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A Cropland Use Model

Theory and Suggestions for Estimating Planted Acreage Response

Paul Gallagher
Robert C. Green

A CROPLAND USE MODEL: THEORY AND SUGGESTIONS FOR ESTIMATING PLANTED ACREAGE RESPONSE. By Paul Gallagher and Robert C. Green, National Economics Division, Economic Research Service, U.S. Department of Agriculture, Washington, D.C. 20250. ERS Staff Report No. AGES840410. November 1984.

ABSTRACT

This report develops the theory of a cropland use model, reports the results of estimating land devoted to crop production, and shows example applications of the cropland use model in estimating planted acreage response for corn, sorghum, barley, oats, soybeans, and wheat. The model first estimates the total amount of land that will be planted to principal crops and then allocates cropland planted to specific crops. The research is aimed at improving modeling work for major field crops.

Keywords: Cropland, acreage response, market equilibrium, land rental market, corn, sorghum, barley, oats, wheat, soybeans.

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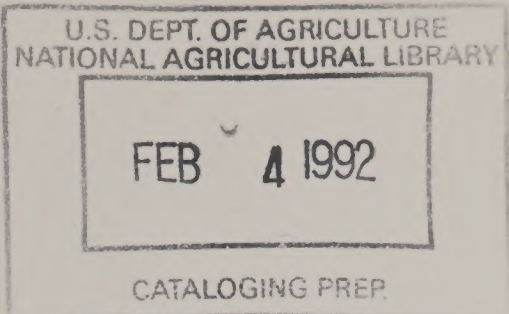
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SUMMARY

The theoretical model for estimating the amount of cropland planted to different crops is based upon two novel assumptions. First, there is a fixed amount of land that can be brought into crop production in a given year. Second, a cash-rent market allocates the use of cropland among crop production, pasture use by livestock, and idleness under government programs. Under these assumptions, it is shown that the amount of land used for crop production depends upon the amount of cropland, conditions in crop and livestock markets, and the attractiveness of government acreage reduction programs. The amount of land used for production of a specific crop depends upon expected profitability of that crop and alternative crops, and the amount of land used in the production of all crops.

Cropland planted to principal crops was estimated for the Corn Belt, Delta, and Great Plains regions. The expected return effect on cropland planted is largest in the Delta. The cattle population effect is largest in the Corn Belt. Effective diversion payment rates have more of an impact in the Corn Belt and Delta regions.

U.S. acreage response equations were estimated for corn, soybeans, wheat, sorghum, barley, and oats. The estimated relations explain a high proportion of the historical variation and the estimated coefficient of the land in production variables are in the intuitive range between zero and one.

Using net returns per acre as an explanatory variable instead of prices relative to costs improved the results. R-squared and t-statistics were higher for net return specifications for corn and soybeans. The net return specification also yielded a positive acreage response to wheat prices, while the prices-relative-to-costs approach resulted in an unexpected, negative acreage response to the prices.

Results support the hypothesis that both supply and demand factors influence amount of land used for crop production. The results stand in contrast to conventional wisdom that land supply is perfectly inelastic and government programs are the main supply shifter.

The mean absolute forecasting error for the endogenous variables was judged to be quite low. In terms of turning point errors, the model did well for 3 of 10 endogenous variables. The model did not perform well over the prediction period. The concept of land planted to principal crops needs further attention, particularly in developing a consistent data series. Identification of appropriate production regions would also be important for the reported modeling concept.

CONTENTS

	Page
INTRODUCTION	1
A CROPLAND USE MODEL: THEORETICAL DEVELOPMENT	2
Land Use Decisions for a Representative Cropland Owner	2
Equilibrium in the Rental Market	5
Specifying Acreage Response Models	6
Implications for Empirical Study of the U.S. Crop Sector	12
ESTIMATES OF TOTAL U.S. CROPLAND PLANTED	13
Estimating Relationships and Data	14
Results	14
Summary	17
ESTIMATES OF CROPLAND UTILIZATION RATES FOR THE	
CORN BELT, DELTA, AND GREAT PLAINS	17
Specification	17
Crop Producing Regions	20
Measuring Expected Crop Prices and Per Acre Returns	20
Corn Belt	24
Delta	25
The Great Plains	28
Summary	37
ESTIMATES OF PLANTED ACREAGE RESPONSE FOR MAJOR FIELD CROPS	37
Corn Acreage Response	38
Soybean Acreage Response	39
Wheat Acreage Response	45
Sorghum Acreage Response	45
Oat Acreage Response	47
Barley Acreage Response	49
Summary	52
EVALUATION OF THE MODEL AND THE	
NEED FOR FURTHER RESEARCH	53
Historical Period: Forecast Errors	53
Historical Period: Turning Point Errors	54
Historical Period: Tests for Bias and Specification Error	55
Prediction Period	58
Need for Futher Research	61
REFERENCES	63
APPENDIX	65

A Cropland Use Model

Theory and Suggestions for Estimating Planted Acreage Response

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INTRODUCTION

This report documents results of acreage response research conducted in support of crops modeling work in the Economic Research Service (ERS). Results confirm the hypothesis that both supply and demand factors influence the amount of land used for crop production. The results stand in contrast to the conventional wisdom that land supply is perfectly inelastic and government programs are the main supply shifter. An important policy implication is that government payments for idling land would tend to remove land from crop production as well as pasture use and fallow, if program rules permit such reductions.

This report is divided into five major sections. The first section presents a theoretical framework for (1) analyzing the amount of land planted to crops and (2) allocating planted cropland to specific crops. This results in an equilibrium model of the land rental market. Specifications for total cropland and acreage response relations are suggested.

Section two presents an estimation of U.S. cropland planted for production which verifies the theoretical model. Results confirm that both supply and demand factors influence the amount of land used for crop production.

The third section presents an alternative specification of response equations for cropland planted to all crops in the Corn Belt, Great Plains, and Delta regions by estimating cropland utilization rates. Multiplying estimated cropland utilization rates by the cropland base is another way of estimating cropland planted for production as reported in section two.

Section four presents U.S. planted acreage response equations for corn, soybeans, wheat, sorghum, barley, and oats. These equations as a system complete the cropland use model. The estimated results confirm the usefulness of this approach.

The fifth section gives an overall evaluation of this approach and suggests the need for further research.

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A CROPLAND USE MODEL: THEORETICAL DEVELOPMENT

Analysts of crop markets are concerned about changes in the amount of land used for agricultural production, as well as the accompanying changes in land allocations to individual commodities. During the grain shortage period of the midseventies, land in production increased by nearly 20 percent as crop prices soared and the government removed acreage controls. Recent set-aside programs have assured a continuation of these interests, as analysts try to determine how much land farmers will remove from production and how they will adjust their output mix on the remaining acreage.

This section describes a framework for (1) analyzing the amount of land planted for agricultural production and (2) allocating planted cropland to specific crops. The framework hinges on the assumption that there is a well-functioning land rental market where the rights to use potential cropland are traded. The decision for a representative cropland owner confronted by land use offers from the cash rent market and the government is first examined. Market equilibrium for rental rates and land use of the available cropland is discussed. Thereafter, the market equilibrium model is cast in econometric parlance, and specifications for total cropland and crop-specific acreage response relations are suggested.

Land Use Decisions for a Representative Cropland Owner

It is a plausible assumption that land use is determined in a market where rights to use land are traded. Indeed, this market is active; as much as one-third of the land used for agricultural production has been rented in recent years (14).^{1/}

One would expect economic agents to bid for land use rights on the basis of values in their respective enterprises. In the private sector, potential cropland is used primarily in crop production. However, pasture use of cropland is common (20 percent of potential cropland), especially during periods of low crop prices. Crop producers' expected net return on the use of a parcel of land is the product of expected price and yield net of per acre costs. Similarly, livestock producers' bids for pasture rights depend on expected livestock prices, animal weight gain, and per acre costs. Rent bids in an efficient market are increased as long as economic profits exist. It is assumed that landowners capture this maximum return for each parcel of land; that is, operators' rent bids are equal to expected returns. Consequently, expected revenues are exactly offset by payments for land and other factors of production (labor, capital, and operating expenses).^{2/}

^{1/} Underscored numbers in parentheses refer to works cited in the References section.

^{2/} Cropland owners could also be efficient operators. However, it does not matter who uses the land; the important assumption is that use is granted to high bidders who are efficient operators.

During periods of low crop prices, the government also bids for the right to "use" cropland. Government offers for removing land from production are complicated and rules tend to change. However, participation is typically voluntary with a government payment for removing some minimum amount of land from production. The programs of the sixties relied on cash payments for reducing acreage of specific commodities within established guidelines (6). In contrast, the set-aside programs of the seventies specified only that producers reduce their planted acreage and fewer restrictions were made on specific commodities. The payoff for participation was that cash payments were made when market prices were weak and "low price insurance" in the form of commodity loans was available on what was produced. In particular, participating farmers received deficiency payments (the farm program yield times the difference between the applicable target price and the national weighted average price received by farmers during the first 5 months of the marketing year) in the event of low crop prices.^{3/}

As a way of illustrating government competition for available cropland, assume that the government offers a fixed rate of payment per acre of cropland for not being used for production. Figure 1 illustrates a representative owner's land use equilibrium for a given set of crop and livestock price expectations. The potential cropland at the owner's disposal is indicated on the horizontal axis. It is assumed that the land parcels are ordered from highest to lowest yield land in crop production. L_T indicates total amount of potential cropland. The vertical axis tabulates rental values (\$/acre) for each parcel of land. O_c and O_p depict offers forthcoming on the market for crop production and pasture, respectively. Both curves are downward sloping, reflecting quality reductions that accompany increasing levels of land use. However, the pasture-offer curve is more elastic since land quality is not as critical in this lower valued use. The government offer is a fixed payment rate per acre idled, as indicated by the horizontal line O_g .

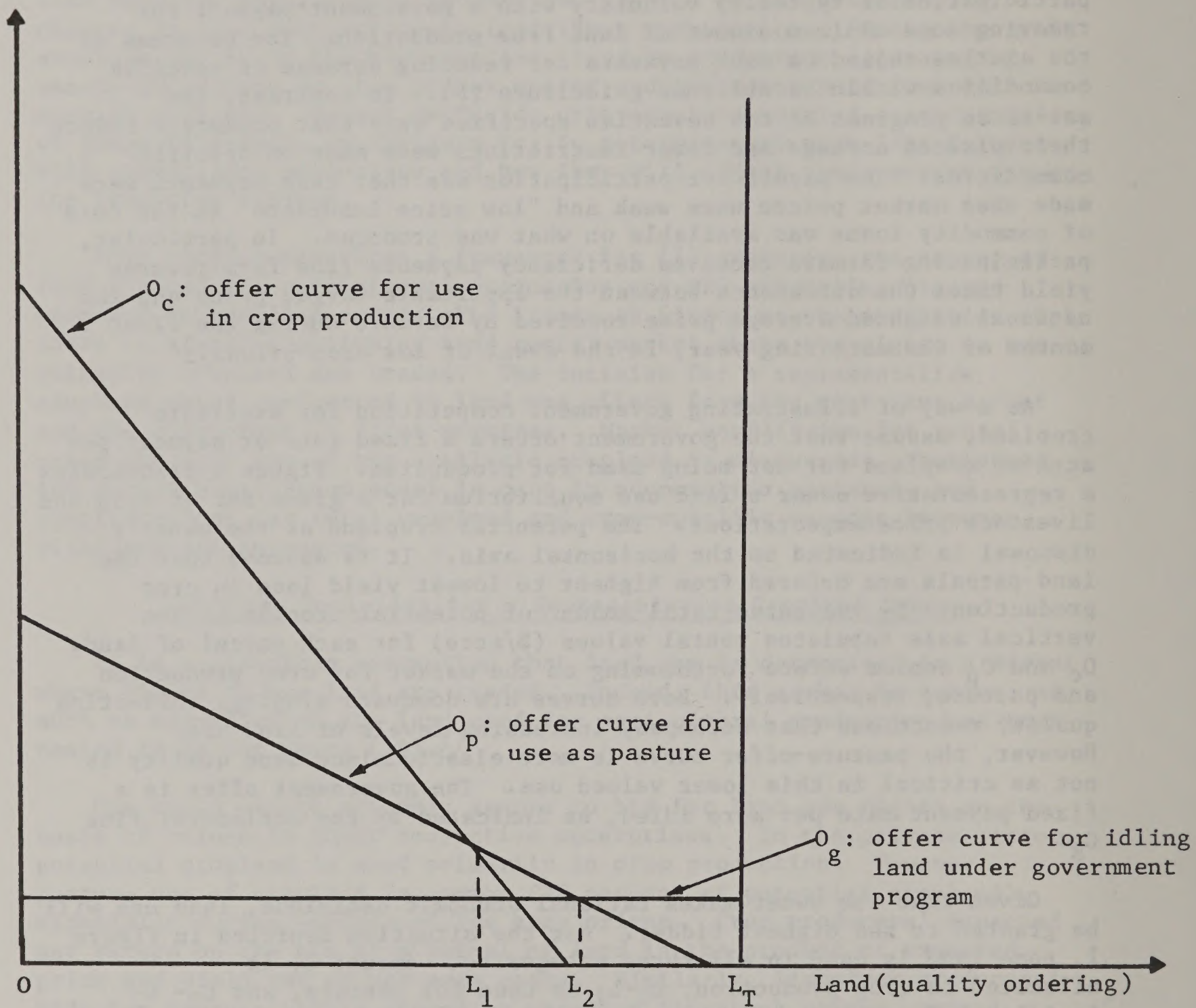
Given that the owner makes rational economic decisions, land use will be granted to the highest bidder. For the situation depicted in figure 1, some land is used in all three categories. Amount L_1 is allocated to crop production, $L_2 - L_1$ is used for pasture, and $L_T - L_2$ is idled under government programs.

Owners could also be confronted with circumstances in which land would not be allocated to all three uses. High expected crop prices or yields would result in a rightward shift in O_c . If the magnitude were large enough, all potential cropland would be allocated to crop production. On the other hand, pasture use would be reduced (or might not occur) when the profitability of livestock production is low or government payment rates are high.

^{3/} See (15 or 18) for more detailed discussion of recent set-aside programs.

Figure 1--Offer Curves and Land Use Determination for a Representative Owner

\$/Acre



This analysis simplifies the landowner's decision problem. It illustrates main sources of competition for cropland use and the factors that influence intensity of this competition. In short, it is reasonable to expect that the amount of cropland used for crop production is influenced by (1) conditions in crop markets, (2) conditions in the livestock economy, and (3) the attractiveness of government acreage reducing programs.

Equilibrium in the Rental Market

The purpose here is to present a plausible model for determining (1) the amount of land used for crop production and (2) rental rates. This analysis continues assumptions analogous to the earlier discussion. In particular, the amount of potential cropland is taken as fixed for a given year. Also, the same land use alternatives are available: (1) crop production, (2) pasture, and (3) idle land under government programs.

The demand for land-use in all three categories is taken as a downward sloping function of the market rental rate. The negative relation between rent and land demand follows from standard production theory in the case of pasture and crop production; derived demand theory holds that demand is negatively related to the own-input price, due to fixed prices and quantities of substitute inputs. Downward-sloping government program demand results from speculative behavior on the part of owners. In particular, it is assumed that owners balance a certain return for renting the land against the uncertain return offered for idling the land under the government program.^{4/}

^{4/} This assumption is well-suited for the set-aside program, where direct cash payments are not the primary incentive for withholding land from production. A speculative demand model amounts to the assumption that the cropland withheld from production will depend on the expected gain:

$$L_g = a(R_g - R_m)$$

where:

- L_g is land idled under the government program,
- R_g is uncertain return from the government for idling the land,
- R_m is certain return from renting the land at the going market rate, and
- a is a constant.

With set-aside, the uncertain return (deficiency payment) depends on the target price and market expectations for upcoming crops. To wit,

$$R_g = k(P_t - P_e)/Y_b,$$

where:

- P_t is target price,
- P_e is expected market price for upcoming production,
- Y_b is base yield, and
- k is a constant for translating to payment rate from planted to diverted acreage.

However, for diversion payments, which were the primary reasons for participating in commodity programs in 1978 and 1979, the returns are very certain.

Land use and rent equilibrium are depicted in figure 2. Plates A, B, and C illustrate forces affecting the supply of land offered for crop production. Plates E and F illustrate factors influencing demand for use in crop production. The equilibrium rental rate and amount of land used for crop production are shown in plate D as the intersection of supply and demand curves.

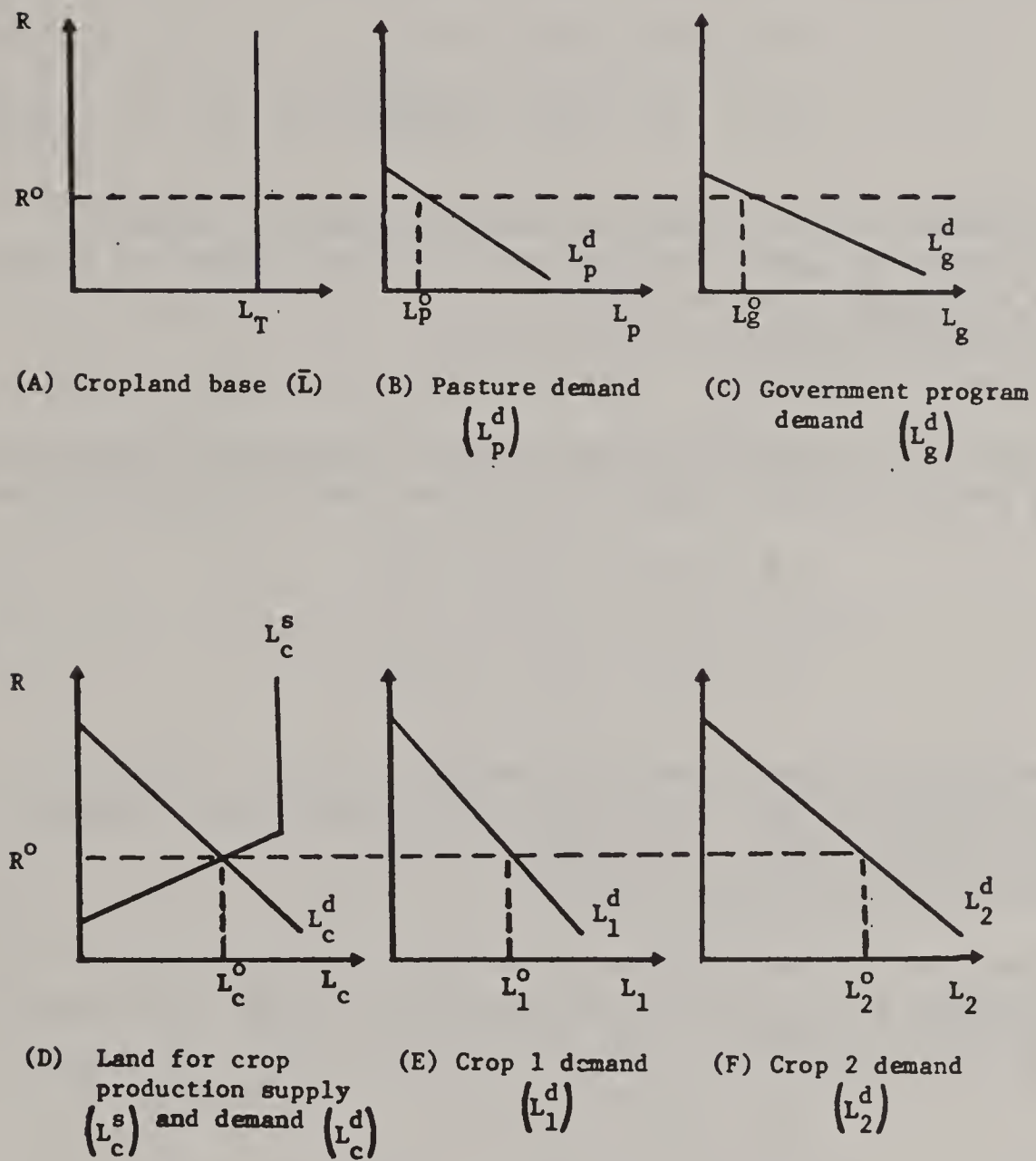
The supply of land offered for crop production (plate D) reflects value of land in alternative uses. That is, supply for crop production is the difference between the fixed supply of potential cropland (plate A) and the demand for land in uses other than agricultural production (plates B and C). Since pasture and government program demands are price responsive, land supply for crop production is moderately elastic for a range of rental rates. When rents rise above the point where pasture and government programs are profitable, however, the entire land base (L_T) is bid into crop production. At high rental rates, the supply of land offered for crop production is perfectly inelastic at L_T .

Demand for land use in crop production is the sum of demands for individual commodities. Two competitive crops are illustrated in plates E and F of figure 2.

Specifying Acreage Response Models

Acreage response analysis typically focuses on the effects of relative commodity price variation and alternative government program provisions on land allocations to specific crops. This is consistent with the model of rental rates and land use. However, it is not the central concern to describe all dimensions of the equilibrium in the rental market. It is shown that the rental market model lends itself to two convenient types of response relations. One type of equation focuses on the determinants for the amount of land used in crop production. The second set of relationships focuses on land allocations to specific commodities, given the total amount of land devoted to crop production. This dichotomy is useful for analyzing provisions of set-aside programs; changes in payment rates influence the amount of land devoted to crop production which, in turn, affects allocations to specific crops.

Figure 2--Equilibrium Rental Rates and Land Use



Assumptions of this algebraic exercise are those of the equilibrium rent market (figure 2). The demand for land use in the production of two crops is represented by the following relations:

$$L_1 = a_1 - b_1 R + c_1 P_1 \quad (1)$$

$$L_2 = a_2 - b_2 R + c_2 P_2 \quad (2)$$

where:

L_1 is amount of land used in the production of crop 1,
 L_2 is expected amount of land used in the production of crop 2,
 P_1 is expected price of crop 1,
 P_2 is expected price of crop 2, and
 R is cash rent rate.

The demand for pasture and government programs represent principal competing uses of land. Linear approximations are again assumed:

$$L_p = a_p - b_p R + c_p P_a \quad (3)$$

$$L_g = a_g - b_g R + c_g P_g \quad (4)$$

where:

L_p is amount of land used for pasture,
 L_g is amount of land idled under the government program,
 P_a is expected price of livestock, and
 P_g is government payment rate.

Equilibrium use of the cropland base (L_T) is guaranteed by requiring that the demand for use in the production of crops (L_C) equals the supply of land offered for crop production:

$$L_C = L_T - L_p - L_g \quad (5)$$

$$L_C = L_1 + L_2 \quad (6)$$

These equations form a closed system of six equations with six endogenous variables (L_1 , L_2 , L_C , L_p , L_g , and R). Five exogenous variables (P_1 , P_2 , P_a , P_g , and L_T) have been included to illustrate important effects. Other influences are included in constant terms.

The supply and demand curve for land in production (figure 2, plate D) are obtained via manipulation of equations (1) through (6). Substituting (3) and (4) into (5) produces the supply relation:

$$L_C = L_T - (a_p + a_g) + (b_p + b_g) R - c_p P_a - c_g P_g \quad (7)$$

The demand function results from substituting (1) and (2) into (6):

$$L_C = (a_1 + a_2) - (b_1 + b_2) R + c_1 P_1 + c_2 P_2 \quad (7a)$$

The most convenient relation from analyzing variation in the amount of land in production is a reduced form equation. This relation is obtained by eliminating R from equations (7) and (7a). From (7a),

$$R = [(a_1 + a_2) + c_1 P_1 + c_2 P_2 - L_c] / (b_1 + b_2)$$

Substituting into (7) and rearranging yields:

$$L_c = A_0 + A_1 P_1 + A_2 P_2 - A_p P_a - A_g P_g + A_T L_T \quad (8)$$

where:

$$A_0 = (a_1 + a_2)(b_p + b_g) - (a_p + a_g) / [(b_1 + b_2) + (b_p + b_g)],$$

$$A_1 = c_1 (b_p + b_g) / [(b_1 + b_2) + (b_g + b_p)],$$

$$A_2 = c_2 (b_p + b_g) / [(b_1 + b_2) + (b_g + b_p)],$$

$$A_p = c_p (b_1 + b_2) / [(b_1 + b_2) + (b_g + b_p)],$$

$$A_g = c_g (b_1 + b_2) / [(b_1 + b_2) + (b_g + b_p)], \text{ and}$$

$$A_T = (b_1 + b_2) / [(b_1 + b_2) + (b_p + b_g)].$$

Equation (8) provides a suitable basis for the empirical analysis of the amount of land used for agricultural production. This relation suggests that land in production is positively related to crop prices (P_1 and P_2), negatively related to value in competing uses (P_a and P_g), and positively related to the base of potential cropland (L_T).

Equation (8) can be restated for an examination of the importance of shifts in supply and demand. Let $r = S_s/S_d$, where $S_s = b_p + b_g$ and $S_d = b_1 + b_2$. Then equation (8) is rewritten as:

$$L_c = a_0 + (c_1 r P_1 + c_2 r P_2 - c_p P_a - c_g P_g + L_T) / (1 + r) \quad (8a)$$

An examination reveals that the influence of supply shifts becomes large as supply becomes inelastic relative to demand ($r \rightarrow 0$). In the limiting case ($r = 0$), the amount of land in crop production changes by the full extent of the supply shift, i.e.,

$$d(L_c)/d(L_T) = 1, d(L_c)/d(P_a) = -c_p, \text{ and } d(L_c)/d(P_g) = -c_g.$$

On the other hand, demand shifts exert smaller influences as supply becomes relatively more inelastic. In the limiting case ($r = 0$), crop prices exert no effect on the amount of land in crop production,

$$d(L_c)/d(P_1) = d(L_c)/d(P_2) = 0.$$

A second set of relationships show that planted acreage allocations to specific crops depend on relative prices of crops and the total amount

of land planted to all crops. For example, consider the acreage response problem for crop 1. Upon substituting equation (2) into equation (6), it follows that

$$L_1 = L_c - a_2 + b_2 R - c_2 P_2.$$

Solving equation (1) for R and substituting it into the above equation yields

$$L_1 = L_c - a_2 + b_2 (a_1 + c_1 P_1 - L_1)/b_1 - c_2 P_2.$$

Rearranging reduces this relation to

$$L_1 = [(b_2 a_1 - b_1 a_2) + b_1 L_c + b_2 c_1 P_1 - b_1 c_2 P_2]/(b_1 + b_2) \quad (9)$$

This same equation is readily expressed in terms of the relative slope of the demand curves for crops 1 and 2. Letting $Z = b_1/b_2$, it follows that

$$L_1 = B_0 + B_1 P_1 - B_2 P_2 + B_c L_c, \quad (9a)$$

where:

$$B_0 = a_1 b_2 - a_2 b_1 / (b_1 + b_2),$$

$$B_1 = c_1/(1 + Z),$$

$$B_2 = Z c_2/(1 + Z), \text{ and}$$

$$B_c = 1/(1 + Z).$$

Empirical analyses with equation (9a) should yield the result that a portion of increased land in crop production will be allocated to the production of commodity 1, i.e., $0 \leq B_c \leq 1$. Additionally, the magnitude of this response depends on the relative ease of substitution between land and other inputs in the production of the commodity alternatives. When input substitution is relatively easier for crop 1, Z is large and B_c is small. The relative ease of input substitution also has a bearing on acreage response to crop prices. High values of Z result in a small acreage response to P_1 and a large response to P_2 .

This approach is readily extended to the analysis of a wider range of crop alternatives. Suppose there are n alternative crops (L_1, \dots, L_n) with corresponding prices (P_1, \dots, P_n). Acreage response functions (equation 9a) may be included for any sub-set of n-j major crops, as long as the commodity set is not exhaustive (i.e., $j \neq 1$). The acreage planted to all j minor crops (L_r) is determined residually through an identity. The arguments leading to the land in crop production relation equation (8) are nearly identical; the only change is a longer list of crop prices for demand shifters. This system of equations is summarized below:

Commodity acreage response

$$L_1 = B_{1,0} + B_{1,1} P_1 - \sum_{i=2}^n B_{1,i} P_i + B_{1,c} L_c \quad (10.1)$$

$$\begin{array}{ccc} \cdot & & \cdot \\ \cdot & & \cdot \\ \cdot & & \cdot \end{array}$$

$$L_{n-j} = B_{n-j,0} + B_{n-j,n-j} P_{n-j} - \sum_{i=1}^{n-j-1} B_{n-j,i} P_i + B_{n-j,c} L_c \quad (10.n-j)$$

Land in Crop Production

$$L_c = A_0 + \sum_{i=1}^n A_i P_i - A_p P_a - A_g P_g + A_T L_T \quad (10.n-j+1)$$

Identity

$$L_r = L_c - \sum_{i=1}^{n-j} L_i \quad (10.n-j+2)$$

where:

$$L_r = \sum_{i=n-j+1}^n L_i$$

endogenous: $L_1, \dots, L_{n-j}, L_r, L_c$, and

exogenous: $P_1, \dots, P_n, P_a, P_g, L_T$.

Implications for Empirical Study of the U.S. Crop Sector

The above theoretical development raises two empirical issues. One unanswered question involves determinants of the amount of land used for crop production; specifically, how important are shifts in supply (conditions in the livestock economy, government programs, and the base of potential cropland) in comparison with demand shifts induced by changes in crop prices? Secondly, proposed acreage response functions are unconventional in that effects of government set-aside, diversion, and acreage restricting policies are not measured directly. Instead, the effect of acreage reducing programs is measured indirectly through the amount of land in production. This approach is appealing for analyzing the acreage reducing programs of recent years, since participating farmers have been relatively free to choose a desired output mix on their remaining acreage.^{5/} Nonetheless, the usefulness of this view of acreage response estimation requires demonstration. This section outlines an approach that could provide answers to these questions.

Study of land in crop production should follow the prescription of equation (8a) and utilize data on area planted to all major crops in the United States. Measurements on the base of potential cropland should be taken from available census reports.^{6/} Government-induced supply shifts might be approximated by "effective diversion payment rates" for the major commodities (6). Pasture use is viewed as a derived demand from the livestock industry. Thus appropriate explanatory variables are (1) the U.S. index of roughage-consuming animal units and (2) an output price index consisting of feeder cattle and nonfed beef components. Demand effects are readily measured with the USDA Statistical Reporting Service (SRS) index of prices received by farmers for crops. The following is a representative estimating relation:

$$AP = a_0 - a_1 \text{ CORPD} - a_2 \text{ WHEPD} - a_3 \text{ RCAU} - a_4 \text{ LIVPI} + a_5 \text{ ACL} + a_6 \text{ PRCL}$$

^{5/} For example, the 1978 feed grain program stipulated only that producers limit plantings to last year's levels; set-aside could come from any crop. However, total planted area of the Normal Crop Acreage (NCA) plus area set-aside plus any additional diverted area could not exceed a farm's NCA (17).

^{6/} Data for intervening years might employ a suitable proxy, such as information for land in farms.

where:

AP is area planted to principal crops, total United States (11),
CORPD is effective diversion payment rate for corn (6),
WHEPD is effective diversion payment rate for wheat (6),
RCAU is index of roughage-consuming animal units (15),
LIVPI is index of livestock prices (11),
ACL is area of cropland (11), and
PRCL1 is index of prices received by farmers for crops lagged 1 year (11).

Acreage response functions for major crops might also employ times series data for the United States. Specifications should follow from equation (9a) but previous studies should provide important shift variables. Corn acreage response functions, for example, should include expected corn and soybean prices, production costs for corn and soybeans, and price risk as additional explanatory variables (2). Moreover, the acreage-in-production constraint should refer to the commodity's dominant production area. For example, 74 percent of 1974 corn acreage was planted in nine States (11). Consequently, acreage planted to principal crops in these States would be the appropriate acreage constraint. A representative set of determinants for corn acreage is:

$$\text{CORAP} = b_0 + b_1 \text{CORPE}/\text{CORCV} - b_2 \text{SOYPE}/\text{SOYCV} - b_3 \text{RISK} + b_4 \text{AP9}$$

where:

CORAP is area planted to corn, total United States,
CORPE is expected price of corn (2),
SOYPE is expected price of soybeans (2),
CORCV is variable cost of corn per acre,
SOYCV is variable cost of soybeans per acre,
RISK is price risk of corn (2), and
AP9 is area planted to principal crops in nine Corn Belt States: Illinois, Iowa, Indiana, Ohio, Minnesota, Nebraska, Missouri, South Dakota, and Wisconsin.

Similar specifications for soybeans and wheat would feature appropriate definitions of the acreage constraint and competitive crops. Soybean acreage would include corn and cotton as the major competitive crops, while the dominant production area would include Corn Belt and Delta States. Most wheat production occurs in Great Plains States and principal competitive crops are sorghum, barley, and cotton.

ESTIMATES OF TOTAL U.S. CROPLAND PLANTED

This section presents empirical estimates of the amount of land use for crop production in the United States, which verify the cropland use model. According to the model, the amount of land used for crop production should depend on the base of potential cropland, conditions in crop and livestock markets, and the attractiveness of government acreage reducing programs.

Models of the amount of land in crop production typically emphasize the government programs. Rosine and Helmberger, for example, stated that:

"The amount of land farmed is assumed to be in perfectly inelastic supply with government acreage diversion programs being the main shifter....The impact of acreage diversion programs is taken into account by simply using planted acreage as the land input" (8).

To the extent that land use competition among crop producers, livestock producers, and government exists, the amount of land in production will respond to both cash-rental rates and market prices in the short run. This issue is addressed in the following statistical analysis.

Estimating Relationships and Data

Analysis of land in production follows the prescription of the conceptual model and utilizes data on area planted to all major crops in the United States (table 1). Measurements on the potential cropland base are taken from census reports.^{7/} Government-induced supply shifts are approximated by "effective diversion payment rates" for the major commodities (6). As pasture use is a derived demand in the livestock industry, appropriate explanatory variables are cattle population and prices for nonfed beef. Demand effects are measured with the index of prices received by farmers for crops. The following is a typical estimating relationship:

$$AP = a_0 - a_1 \text{ CORPD} - a_2 \text{ WHEPD} - a_3 \text{ COF} - a_4 \text{ CATPF} + \quad (11) \\ a_5 \text{ ACL} + a_6 \text{ PRCL1}$$

where:

- AP is area planted to principal crops in the United States, 37 States (mil acres),
- CORPD is corn effective diversion payment rate (\$/bu),
- WHEPD is wheat effective diversion payment rate (\$/bu),
- COF is cattle on farms in the United States on January 1 (mil),
- CATPF is feeder cattle price (steers), January-December average (\$/cwt),
- ACL is U.S. cropland (mil acres), and
- PRCL1 is an index of prices received by farmers for crops in the previous calendar year (1967 = 100).

Results

Least squares estimation of total U.S. cropland planted over the 1950-1978 period confirmed the hypothesis of competition for land use

^{7/} Census data on the cropland base is reported every 5 years. Values for intervening years were computed with linear interpolations.

Table 1--Data for U.S. land in production equation

Year	AP	CORPD	WHEPD	COF	CATP	ACL	PRCL1
	<u>Mil. acres</u>	<u>--Dols./bushel--</u>		<u>Mil. head</u>	<u>Dols./cwt.</u>	<u>Mil. acres</u>	<u>1967=100</u>
1950	353.246	0	0	77.963	7.332	478.00	111.0
1951	362.922	0	0	82.083	10.572	474.75	103.0
1952	356.093	0	0	88.072	.140	471.50	117.0
1953	360.461	0	0	94.241	-8.996	468.25	118.0
1954	354.776	0	0	95.679	-5.738	465.00	106.0
1955	353.715	0	0	96.592	-5.634	463.40	107.0
1956	343.359	0	.840	95.900	-5.250	461.80	102.0
1957	330.871	.043	.840	92.860	.762	460.20	104.0
1958	325.592	.052	.760	91.176	7.036	458.60	99.0
1959	329.401	0	0	93.322	5.444	457.00	99.0
1960	324.470	0	0	96.236	1.436	454.40	98.0
1961	308.594	.192	0	97.700	.940	451.80	99.0
1962	299.851	.192	.250	100.369	.984	449.20	100.0
1963	305.977	.112	.190	104.488	-1.436	446.60	103.0
1964	298.454	.180	.040	107.903	-4.074	444.00	107.0
1965	297.214	.180	.090	109.000	-.200	450.20	106.0
1966	293.062	.248	.160	108.862	2.796	456.40	103.0
1967	305.781	.150	0	108.783	1.634	462.60	106.0
1968	299.384	.241	0	109.371	2.826	468.80	100.0
1969	291.153	.241	.200	110.015	5.648	475.00	100.0
1970	293.211	.231	.180	112.369	4.596	473.00	97.0
1971	305.830	.160	0	114.578	5.006	471.00	100.0
1972	294.609	.260	.180	117.862	.470	469.00	108.0
1973	318.682	.080	.320	121.539	7.626	467.00	114.0
1974	326.495	0	0	127.788	2.626	465.00	175.0
1975	332.366	0	0	132.028	-1.882	465.00	224.0
1976	336.256	0	0	127.980	1.694	465.00	201.0
1977	343.121	0	0	122.810	1.672	465.00	197.0
1978	333.148	.170	1.180	116.265	19.322	465.00	192.0

among crop producers, livestock producers, and government. In preliminary regressions, however, effective diversion payment rates for commodities other than corn and livestock price were not statistically significant. Livestock price (expressed as a deviation about a 5-year moving average) and effective diversion payment rates for commodities other than corn are dropped in equation (12). Equation (13) is a similar specification, except that the livestock price has been dropped. Numbers in parentheses are t-values, while numbers in brackets are elasticities at mean values.

$$\begin{aligned}
 AP = & 103.98196 - 137.527 \text{ CORPD} - 0.920497 \text{ COF} - 0.36064 \text{ CATP} + \quad (12) \\
 & (1.25) \quad (-5.36) \quad -4.93 \quad (-1.2) \\
 & \quad \quad [-0.036] \quad [-0.299] \quad [-0.003] \\
 & 0.63705 \text{ ACL} + 0.28106 \text{ PRCL1} \\
 & (3.58) \quad (3.80) \\
 & [0.913] \quad [0.105]
 \end{aligned}$$

$$R^2 \text{ (Adj)} = 0.899 \quad S = 7.452 \quad D.W. = 1.16$$

where: $CATP_t = CATPF_t - CATMA_t$, and

$$\begin{aligned}
 & 5 \\
 CATMA_t = & .2 \sum_{i=1}^5 CATPF_{t-i}
 \end{aligned}$$

$$\begin{aligned}
 AP = & 140.9564 - 136.1092 \text{ CORPD} - 0.86179 \text{ COF} + 0.55252 \text{ ACL} \quad (13) \\
 & (1.810) \quad (-6.720) \quad (-4.730) \quad (3.350) \\
 & \quad \quad [0.040] \quad [0.281] \quad [0.790] \\
 & + 0.25108 \text{ PRCL1} \\
 & (3.560) \\
 & [0.094]
 \end{aligned}$$

$$R^2 \text{ (Adj)} = 0.897 \quad D.W. = 0.9903 \quad S = 7.525$$

Dependent variable mean: 323.283

An examination of coefficients and t-values reveals that all variables have correct signs and nearly all variables are significant at standard confidence levels; only the the livestock price variable is marginally significant. Magnitudes of estimated coefficients are also reasonable. If the cropland base expands by 1 million acres, for example, land planted for crop production will expand around 0.6 million acres. An additional 1 million cattle on farms (COF) reduces the area planted to crops by about 0.9 million acres. Finally, the elasticity with respect to crop prices is positive (0.094 to 0.105) and significant,

indicating that rising expected crop prices draw land into crop production.

These relations explain a large amount of historical variation in planted area: R-squared statistics are in the neighborhood of 0.9. As figures 3 and 4 indicate, however, most of the large errors occur early in the sample period. Durbin-Watson statistics range from the indeterminate region to a confirmation of positive autocorrelation. Thus, it is possible that coefficient estimates and R-squared statistics could be improved with additional explanatory variables or a more appropriate functional form.

Summary

These results confirm the hypothesis that both supply and demand factors influence the amount of land used for crop production. These results stand in contrast to the simpler view that the land supply is perfectly inelastic and government programs are the main supply shifter. The important policy implication is that government payments for idling land from crop production also tend to remove land from pasture use and fallow. The extent to which this could occur would depend on rules and regulations regarding how land idling programs actually work.

Possible extensions of this study might aim at improved estimates of the response to specific commodity payment rates. Since efforts to isolate effects of these payment rates in the aggregate were not successful, future work might employ regional or State relationships.

ESTIMATES OF CROPLAND UTILIZATION RATES FOR THE CORN BELT, DELTA, AND GREAT PLAINS

Estimates of U.S. cropland planted to principal crops were presented in the previous section. During the attempt to estimate regional cropland planted to principal crops, an alternative specification proved to be preferred. Under the alternative specification, the model explains the proportion of cropland planted as opposed to total cropland planted. Therefore, estimates of the proportion of cropland planted in major agricultural regions are reported in this section.

Specification

This empirical study builds on two critical assumptions. First, the base of potential cropland is fixed within the time period relevant to annual planting decisions. Second, the major competing uses for this land are crop production, temporary pasture, and idle land under government programs. The main consequence for empirical analysis is that the factors which "shift" the demand for cropland in any of these uses affect the amount of this land eventually used for crop production. The strength of the demand for pasture use is measured by the number of cattle on farms in the region or cattle population divided by available

Figure 3--Actual and Estimated Acres Planted from Equation 12

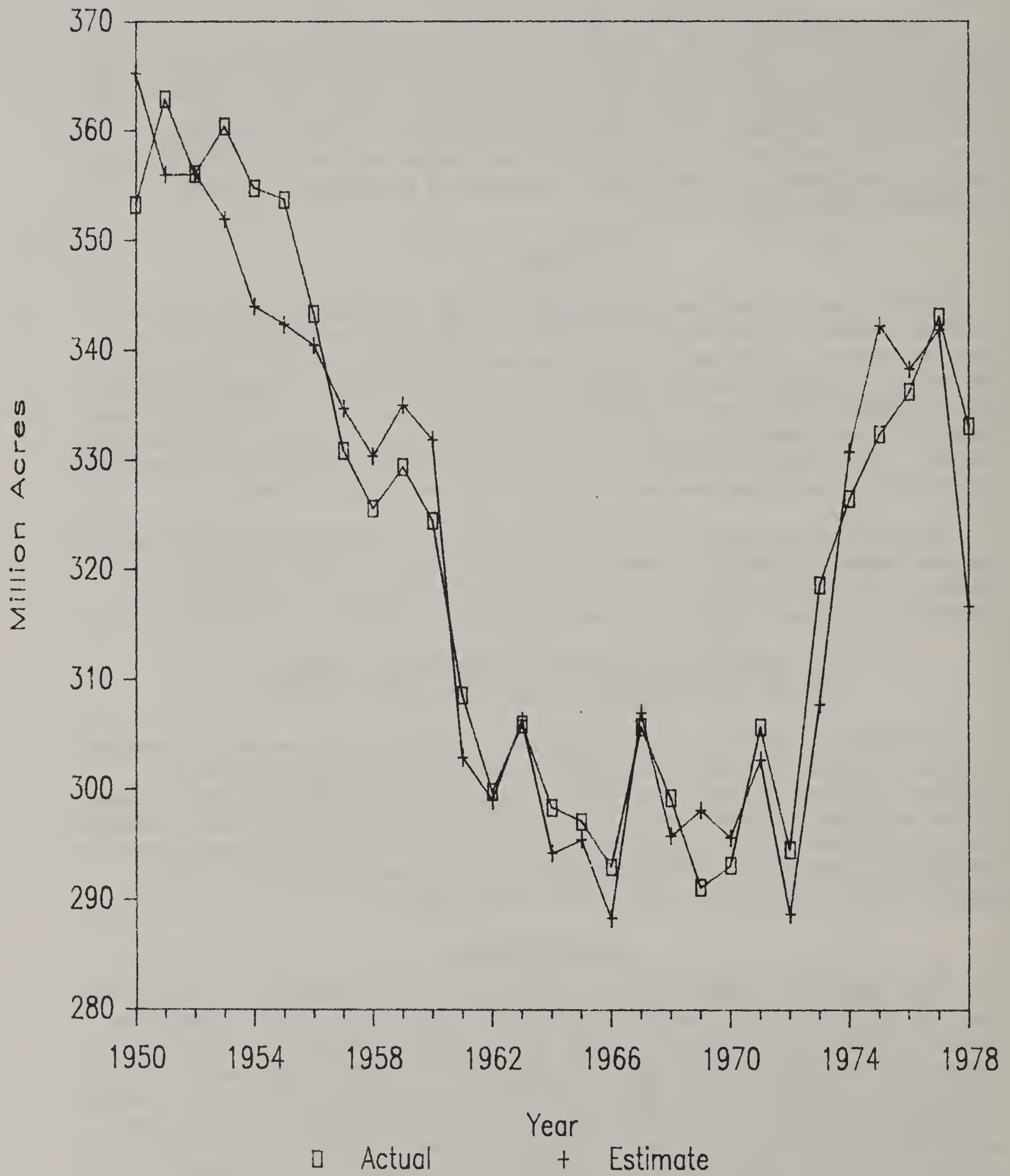


Figure 4--Actual and Estimated Acres Planted from Equation 13



cropland. Finally, attractiveness of government acreage-idling programs is measured by "effective diversion payment rates" for individual crops. A typical estimating relationship is shown below:

$$U = a + b \text{ NR} - c \text{ COF} - d \text{ PD} \quad (14)$$

where:

- U is cropland utilization rate: the area planted in all crops divided by potential cropland (percent),
- NR is expected net return for producing crops (\$/acre),
- COF is cattle on farms (mil head), and
- PD is effective diversion payment rate for idling land under government programs (\$/bu).

Crop Producing Regions

As crop production alternatives are not uniform across the United States, several regions with common sets of crop alternatives were specified. Figure 5 depicts regions defined for this study. Table 2 shows the amount of land planted to all principal crops from 1954 to 1978 and table 3 illustrates distribution of U.S. corn, soybean, wheat,

sorghum, barley, and oat areas among the crop production regions. The Corn Belt is broadly specified to include the usual Midwestern States as well as several Great Lakes States. The major crop production alternatives in this region are corn and soybeans. Large acreages of soybeans are also planted in the Delta, where the major competitive crop is cotton. Three regions plant the bulk of U.S. wheat: Northern Plains, Southern Plains, and West Coast. There are several local crop production alternatives for wheat: sorghum and cotton are planted in the Southern Plains, while barley is grown in the Northern Plains and West Coast. Oat plantings are scattered throughout the United States.

Measuring Expected Crop Prices and Per Acre Returns

Acreage response analysis typically builds on the assumption that expected prices influence acreage decisions and that past market prices or current levels of price support are suitable measures of expected prices. Input price and cost inflation of recent years has led to the suggestion that prices relative to costs or per acre profitability might better serve as the appropriate supply inducing variables. Accordingly, the analysis that follows contains acreage response functions which feature alternative specifications: expected prices and per acre returns are specified as the supply inducing variable. This section outlines the methods used in constructing expected prices and per acre returns.

Expected prices are taken as a weighted average of market and support prices (2). The function shown below has the feature that there is a varying response to support and market prices, depending on market conditions:

Figure 5--Major Crop Producing Regions

Major Crop Producing Regions

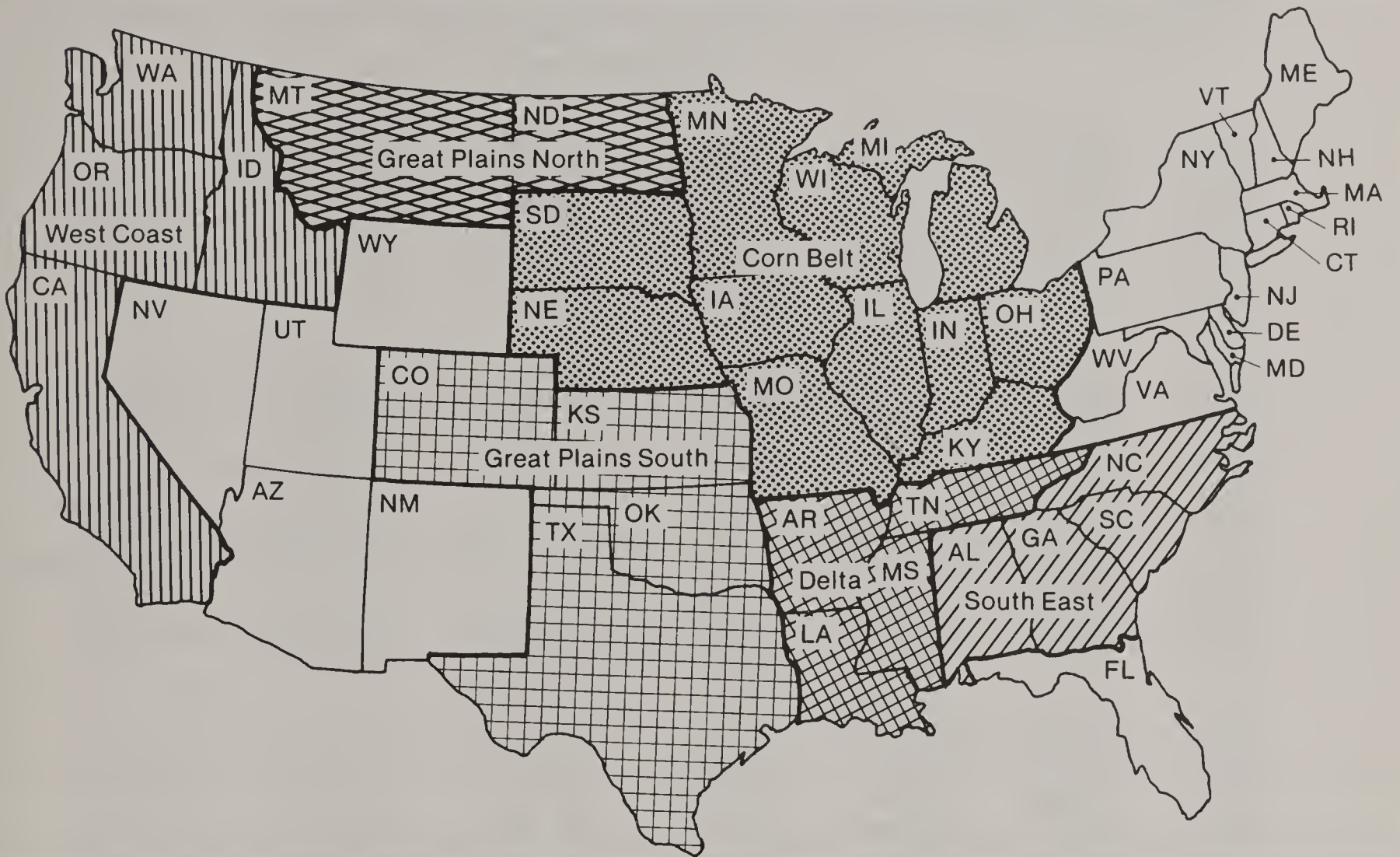


Table 2--Area planted to principal crops^{1/}

Year	Corn Belt 2/	Delta 3/ 	South-east 4/	Great Plains		West Coast 7/
				Northern Plains 5/	Southern Plains 6/	
<u>Million acres</u>						
1954	162.718	19.115	17.173	31.469	66.732	17.632
1955	161.457	19.495	17.216	30.684	61.694	17.416
1956	154.176	18.882	16.555	30.418	57.258	17.488
1957	153.994	17.700	15.532	30.446	60.643	17.436
1958	154.178	17.544	14.684	30.091	64.123	17.444
1959	155.279	18.424	15.737	29.294	64.277	17.477
1960	155.045	17.169	14.066	28.913	63.698	16.855
1961	142.001	17.063	13.405	25.296	59.586	16.779
1962	138.644	16.782	12.420	26.653	55.301	15.983
1963	143.622	17.179	12.603	26.884	54.596	16.345
1964	142.089	18.047	12.234	26.835	55.989	16.884
1965	141.833	18.213	11.610	27.373	55.468	16.726
1966	141.527	17.893	11.168	26.789	53.919	16.442
1967	147.404	19.378	11.972	28.398	55.592	17.254
1968	141.719	20.150	11.578	27.667	56.304	16.998
1969	136.677	20.093	11.227	26.801	55.682	16.493
1970	138.436	20.434	11.244	26.732	54.877	16.761
1971	146.756	20.824	12.168	28.639	55.102	26.959
1972	140.938	20.851	11.684	26.346	53.148	16.742
1973	152.744	21.081	12.495	28.889	60.403	17.535
1974	157.558	21.503	13.101	29.147	60.529	18.597
1975	159.097	22.158	13.438	29.542	62.663	18.836
1976	161.254	23.632	13.609	30.528	61.146	19.277
1977	163.915	24.622	14.257	30.743	63.989	18.538
1978	159.915	25.151	14.245	29.916	59.000	18.308

^{1/} Area planted to principal crops is a data series compiled by SRS. This series is not available over the entire study period. Prior to 1964, SRS compiled harvested acreage for only 59 principal crops. Because of time and funding constraints, Gallagher was not able to calculate a new series that would have been consistent over the entire study period. Subjected to available data, he spliced the two series together in order to obtain a measure of area planted to principal crops.

For the 1964-1978 period, crop area included is as follows: planted acres for corn, sorghum, oats, barley, durum and other spring wheat, rice, soybeans, flaxseed, peanuts, sunflower seed (beginning in 1975), popcorn, cotton, dry edible beans, dry edible peas, potatoes, sweet potatoes, and sugar beets; harvested acres for winter wheat, rye, all hay, tobacco and sugarcane. (See 11, p. 438).

(Continued)

Table 2 footnotes continued--

For the 1954-1963 period, harvested acreage for 59 principal crops is adjusted to conform with the "planted acreage" series available for the 1964 to 1978 period. Regressions of harvested acreage (AH) on acreage planted (AP) were used to adjust the earlier data:

- (1) Corn Belt -- $AH_1 = 11,212.8 + 0.9078 AP_1$
- (2) Delta -- $AH_2 = -805.2 + 1.012 AP_2$
- (3) Southeast -- $AH_3 = -814.845 + 1.011 AP_3$
- (4) Northern Plains -- $AH_4 = -2,509.99 + 1.058 AP_4$
- (5) Southern Plains -- $AH_5 = 693.15 + 0.9446 AP_5$
- (6) West Coast -- $AH_6 = 879.75 + 0.9879 AP_6$

2/ States included: Iowa, Illinois, Indiana, Minnesota, Ohio, Missouri, Michigan, Wisconsin, Kentucky, South Dakota, Nebraska.

3/ States included: Arkansas, Mississippi, Louisiana, Tennessee.

4/ States included: North Carolina, Alabama, Georgia.

5/ States included: North Dakota, Montana.

6/ States included: Kansas, Oklahoma, Texas, Colorado.

7/ States included: Washington, Oregon, Idaho, California.

Table 3--Percentage of 1975 crop acreage occurring in specified regions

Crop	Wheat Belt							Total U.S.
	Corn Belt	Delta	Great Plains		West Coast	Total	Other	
			Northern	Southern				
			Plains	Plains				
			Percent					
Corn	78.00	1.38	0.75	5.27	0.86	6.88	13.74	100.0
Soybeans	61.99	21.87	.33	3.19	0	3.52	12.62	100.0
Wheat	23.66	1.46	21.07	39.81	9.42	70.29	4.59	100.0
Sorghum	18.30	2.20	0	73.80	1.27	75.07	4.43	100.0
Barley	17.60	.30	38.30	5.40	27.90	71.60	10.50	100.0
Oats	63.44	3.09	10.67	11.31	3.85	25.83	7.64	100.0

$$PE = PS + c [\ln(D + 1)(D + 1) - D], \text{ as}$$

$$D = PML1 - PS,$$

where:

PML1 is market price for crop i in the previous year,
 PS is support price for crop i in the current year, and
 PE is expected price for crop i in the current year.

The coefficient c was chosen so that $d(PE)/d(PML1) = 1.0$ when D reached its maximum value over the historical period. In cases where acreage restrictions were present during the sixties, "effective" support price variables were used for PS (6). After 1965, price support payments ceased to be related to planted acreage and were based in terms of a required minimum diversion. In effect, the support payment was an incentive to divert acres from production. Then the effective support price is the loan rate. However, in years of no acreage restrictions, the support payment is a supplemental payment for production and is incorporated into the effective support price.

Other estimates feature expected net returns over variable costs as the appropriate supply inducing variable:

$$NR = PE \cdot YE - CV$$

where:

NR is expected returns per unit of land from production of crop i,
 PE is expected price of crop i,
 YE is expected yields of crop i, and
 CV is variable costs per unit of land for crop i.

Expected prices are defined above. Expected yields are taken from regressions of actual yield on trend (linear and quadratic terms) over the period 1954-1978. Cost data are taken from cost of production surveys for the 1974-1978 period. Cost data for earlier years are taken from a combination of input price and quantity indices. The details of the computation of expected yields, costs, and net returns are reported in the Appendix.

Corn Belt

The net returns variable for the Corn Belt is a weighted average of corn, soybeans, wheat, and oats; the percentage weights are 49.3, 41.3, 6.2, and 3.2, respectively.^{8/} The effective diversion payment rate measures attractiveness of government acreage reducing programs.

^{8/} Expected per acre returns for individual crops were documented earlier. Also, the weights are given by the percentage of producer's operating income derived from a particular crop in the region over the 1975-77 period.

Similar results are shown in equations (15) and (16). Equation (15) is a straightforward application of (14) while in (16) the cattle population is divided by available cropland. Both of these equations explain much of the historical variation with R-squared statistics of about 0.90 in spite of an outlier in 1969. Moreover, all variables have correct signs and most are statistically significant; equation (16) suggests that the response to crop profitability is not significant.

Plots of actual and estimated utilization rates are shown in figures 6 and 7. Numbers in parentheses are t-values.

$$\text{UCB} = 1.03497 + 0.0004136 \text{ NRCB} - 0.35202 \text{ CORPD} - 0.006178 \text{ COFCB} \quad (15)$$

(16.62) (2.03) (-10.81) (-3.64)

$$R^2 (\text{Adj}) = 0.882 \quad \text{D.W.} = 1.28 \quad S = 0.01435$$

$$\text{UCB} = 1.001758 + 0.000077187 \text{ NRCB} - 0.37184 \text{ CORPD} \quad (16)$$

(16.09) (0.47) (-11.29)

$$- 0.99197 \text{ COFCB/LCB}$$

(-3.10)

$$R^2 (\text{Adj}) = 0.868 \quad \text{D.W.} = 1.13 \quad S = 0.0151$$

Dependent variable mean: 0.7636

Historical period: 1954 to 1979

Variable definitions:

- UCB is cropland utilization rate for the Corn Belt, area planted to all crops divided by total cropland (percent),
- NRCB is expected net return for Corn Belt production; a weighted average of expected net returns for corn, soybean, wheat, and oat production (\$/acre),
- CORPD is effective diversion payment rate for corn (\$/bu),
- COFCB is cattle on farms in Corn Belt on January 1 (mil head), and
- LCB is cropland in the Corn Belt (mil acres).

Delta

The expected returns variable for the Delta is a weighted average of returns for soybeans, cotton, and wheat (percentage weights are 74.6, 22, and 2.5, respectively). The effective diversion payment rate for cotton measures the government acreage-idling effect. Similar equations with different cattle population effects are presented.

The R-squared statistics are lower than those for the Corn Belt, primarily because the set of independent variables fails to explain the cyclical behavior of utilization rates during the fifties and sixties. In both equations, a strong crop price response is indicated and the cotton diversion effect helps explain historical variation. In equation (17), the cattle population is not a significant explanatory variable.

Figure 6--Actual and Estimated Cropland Utilization Rates
for the Corn Belt from Equation 15

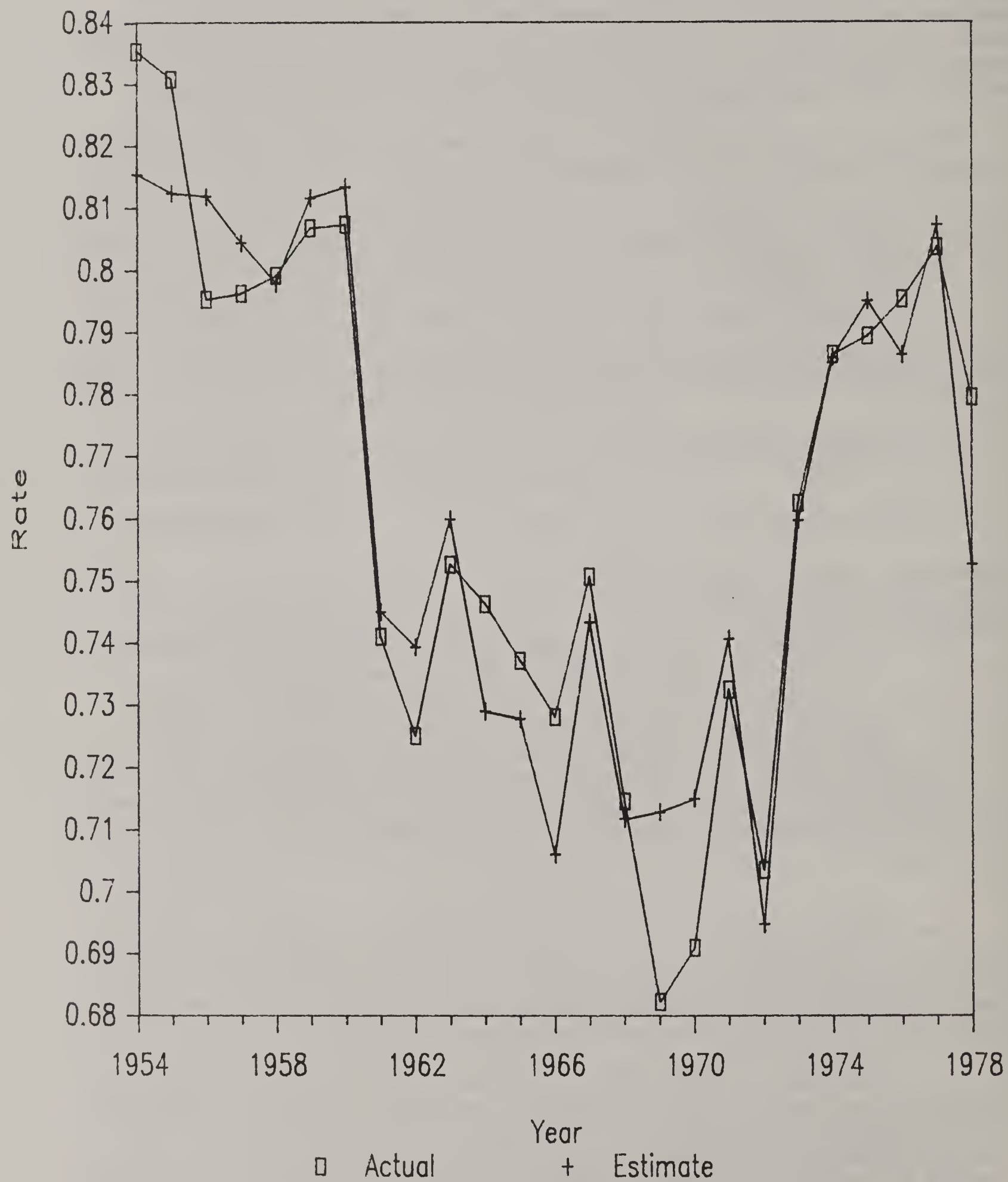
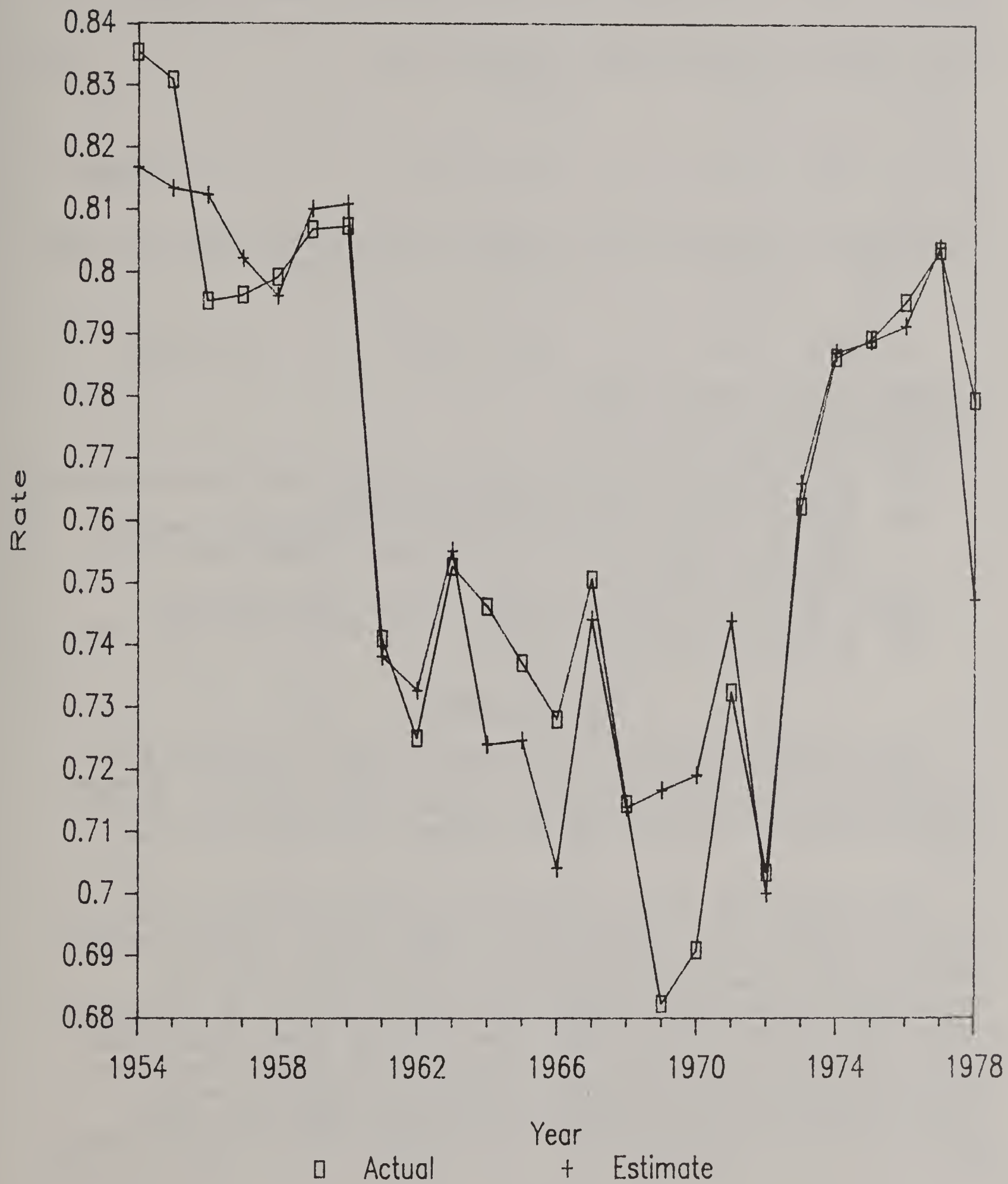


Figure 7--Actual and Estimated Cropland Utilization Rates
for the Corn Belt from Equation 16



However, the cattle variable, when expressed as cattle on farms relative to cropland, has the correct sign and improves the R-squared statistic. Plots of actual and estimated utilization rates are shown in figures (8) and (9).

$$\text{UDL} = 0.57308 + 0.0014779 \text{ NRDL} - 0.065039 \text{ COTPD} \quad (17)$$

(38.07) (5.13) (-1.41)

$$R^2 (\text{Adj}) = 0.580 \quad \text{D.W.} = 1.77 \quad S = 0.02156$$

$$\text{UDL} = 0.65745 + 0.0015907 \text{ NRDL} - 0.069489 \text{ COTPD} - 0.34288 \text{ COFDL/LDL} \quad (18)$$

(12.15) (5.54) (-1.55) (-1.62)

$$R^2 (\text{Adj}) = 0.607 \quad \text{D.W.} = 1.80 \quad S = 0.0208$$

Dependent variable mean: 0.6292

Historical period: 1954 to 1979

Variable definitions:

UDL is cropland utilization rate in the Delta, area planted to all crops divided by total cropland (percent),

NRDL is expected net return for Delta crop production; a weighted average of expected returns for soybean, cotton, and wheat production (\$/acre),

COTPD is effective diversion payment rate for cotton (\$/cwt),

COFDL is cattle on farms in the Delta on January 1 (mil head), and

LDL is Delta cropland (mil acres).

The Great Plains

Initial estimates of cropland utilization rates in the Great Plains followed the same specification as in the Corn Belt and Delta. However, that approach proved to be unsuitable. Therefore, analysis of the Great Plains is slightly different from the analyses for the Corn Belt and Delta.

First, utilization rates are computed as the ratio of harvested area to total cropland. The interpretation is that the land is not "used for crops" in the high-risk regions unless it is harvested. This is plausible since Great Plains abandonment rates are typically high and swing widely in response to weather and economic forces. In the Southern Plains, for example, failing winter wheat is often plowed under in the spring and planted to another crop. Also, pasture use of winter wheat does not detract from grain yields if cattle are removed in early spring. However, grazing through the spring and summer is a common practice when cattle are valuable, wheat is cheap, or the crop is failing (3).

Figure 8--Actual and Estimated Cropland Utilization Rates for the Delta from Equation 17

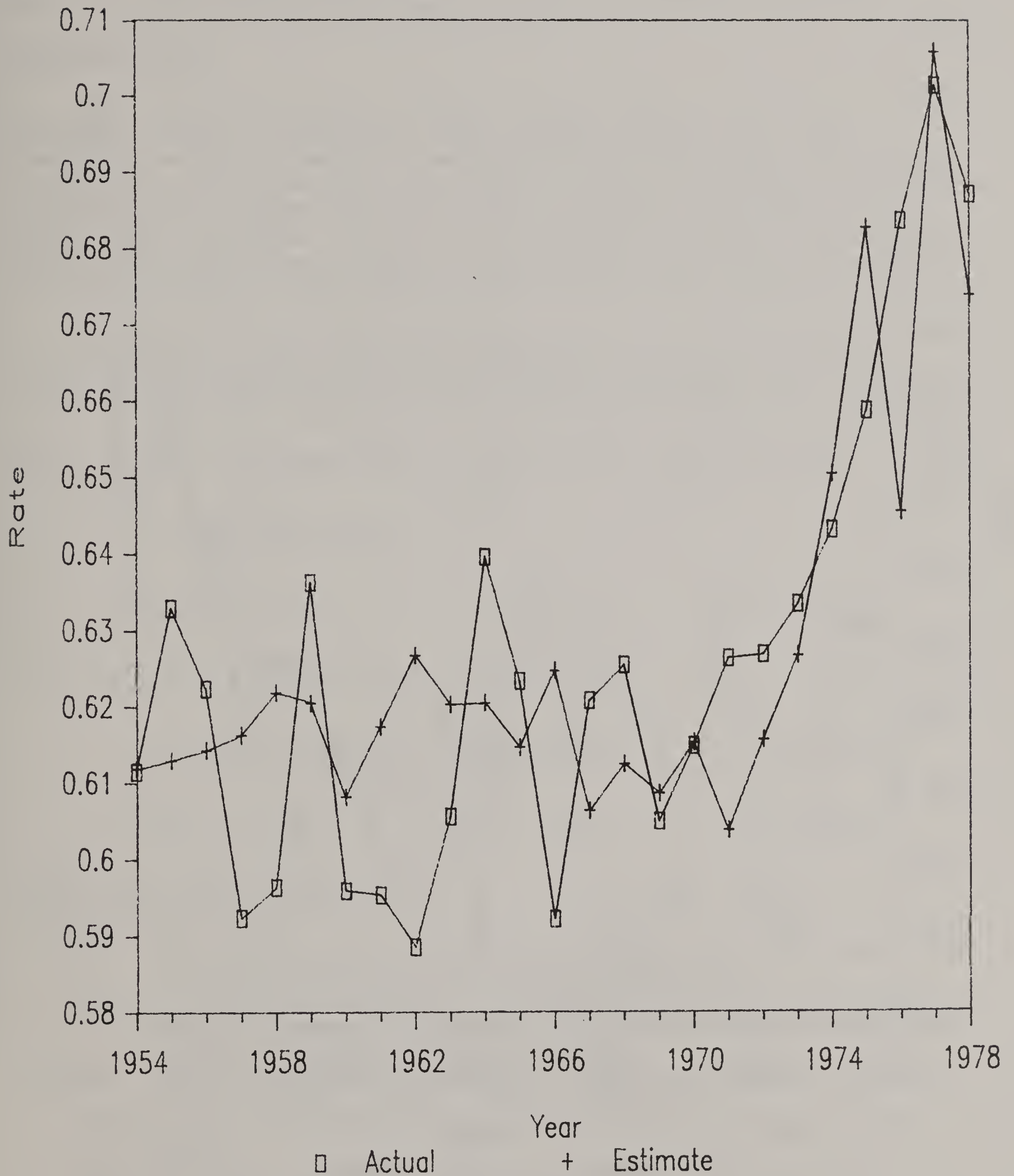
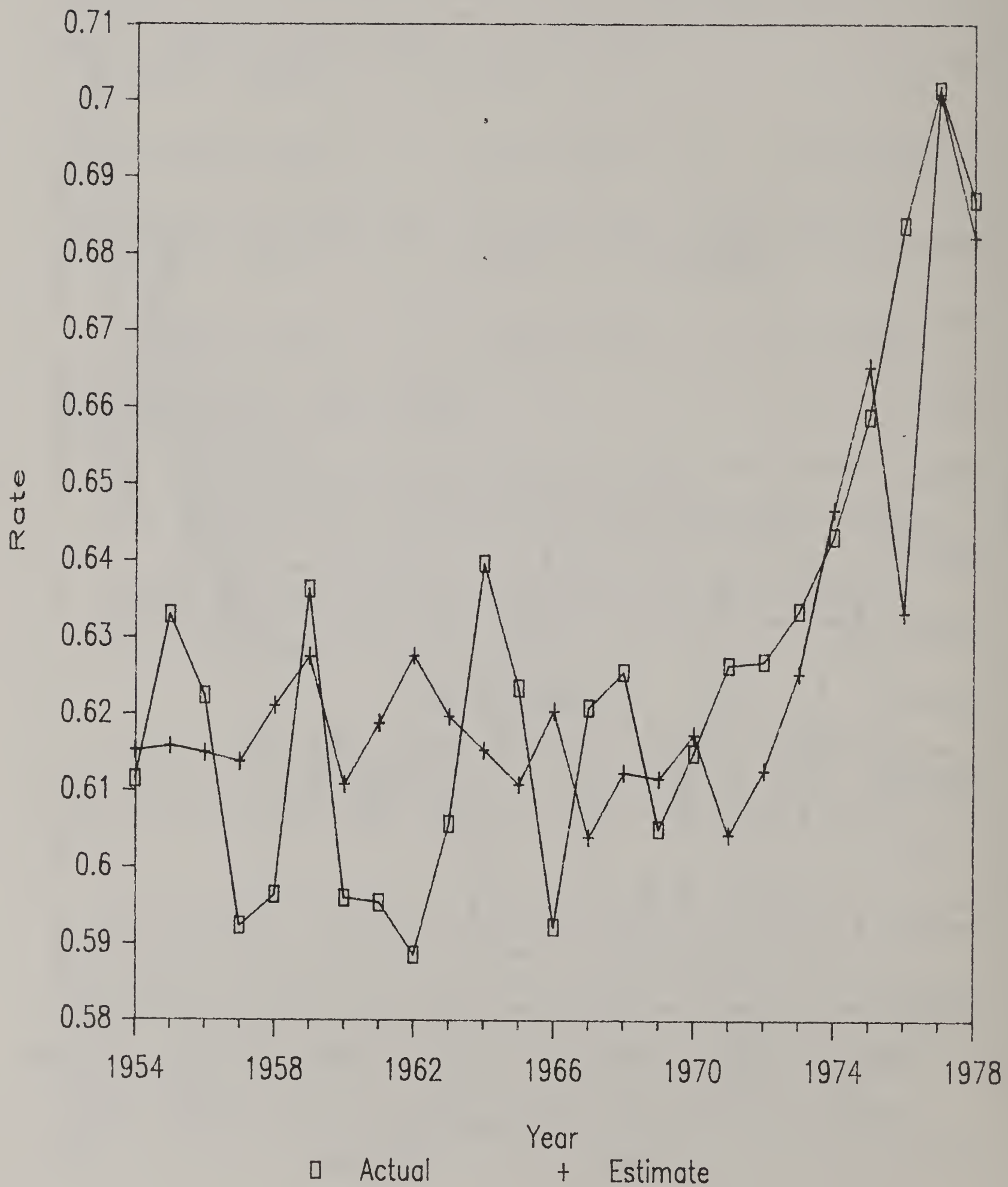


Figure 9--Actual and Estimated Cropland Utilization Rates
for the Delta from Equation 18



Second, regional yield, cost, and price data for wheat are used in separate analysis of utilization rates in the Southern and Northern Plains. This enhances measurement of quality differences, regional weather conditions, and local market prices.

Southern Plains

The expected net returns variable for the Southern Plains is a weighted average of returns for wheat, sorghum, cotton, and corn; percentage weights on per acre returns for individual crops are 48, 19.4, 20.9, and 11.8, respectively. The attractiveness of government acreage-idling programs is measured with an average "effective diversion payment rate" variable. This variable, expressed in \$/acre, was formed by multiplying per bushel payment rates by trend yields and forming a weighted average with the weights used in the expected returns variable.

Equations (19) and (20) both confirm that the profitability of crop production, cattle population, government programs, and weather conditions all influence the Southern Plains utilization rate. Plots of actual and estimated utilization rates are shown in figures (10) and (11).

$$\text{USP} = 0.67098 + 0.0014684 \text{ NRSP} - 0.0027755 \text{ PDSP} - 0.0047524 \text{ COFSP} \quad (19)$$

(20.29) (2.14) (-5.46) (-3.93)

$$+ 0.038052 \text{ PERYSP}$$

(1.75)

$$R^2 (\text{Adj}) = 0.661$$

$$\text{D.W.} = 1.59$$

$$S = 0.0251$$

$$\text{USP} = 0.67931 + 0.00143288 \text{ NRSP} - 0.0028032 \text{ PDSP} \quad (20)$$

(19.13) (2.04) (-5.41)

$$- 0.47769 \text{ COFSP/LSP} + 0.036161 \text{ PERYSP}$$

(-3.74) (1.63)

$$R^2 (\text{Adj}) = 0.647$$

$$\text{D.W.} = 1.56$$

$$S = 0.0256$$

Dependent variable mean: 0.5878

Historical period: 1954 to 1979

Variable definitions:

- USP is cropland utilization rate in the Southern Plains, area harvested divided by total cropland (percent),
- NRSP is expected net returns for Southern Plains crop production; a weighted average of expected net returns for wheat, sorghum, cotton, and corn production (\$/acre),
- PDSP is a weighted average of effective diversion payment rates for wheat, sorghum, cotton, and corn (\$/acre),
- COFSP is cattle on farms in the Southern Plains on January 1 (mil head),
- PERYSP is ratio of actual yield to "trend yield" (percent), and
- LSP is Southern Plains cropland (mil acres).

Figure 10--Actual and Estimated Cropland Utilization Rate
in the Southern Plains from Equation 19

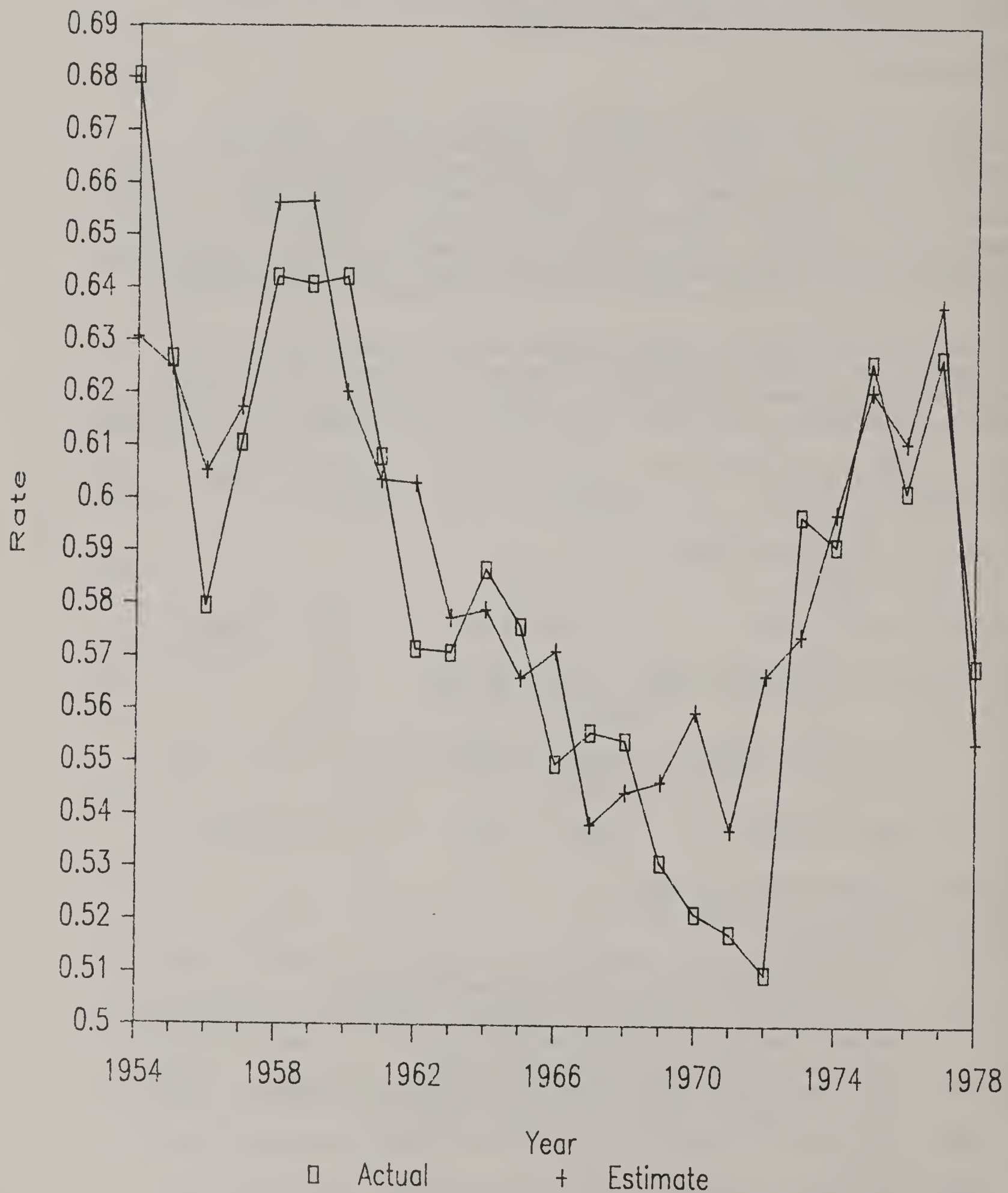
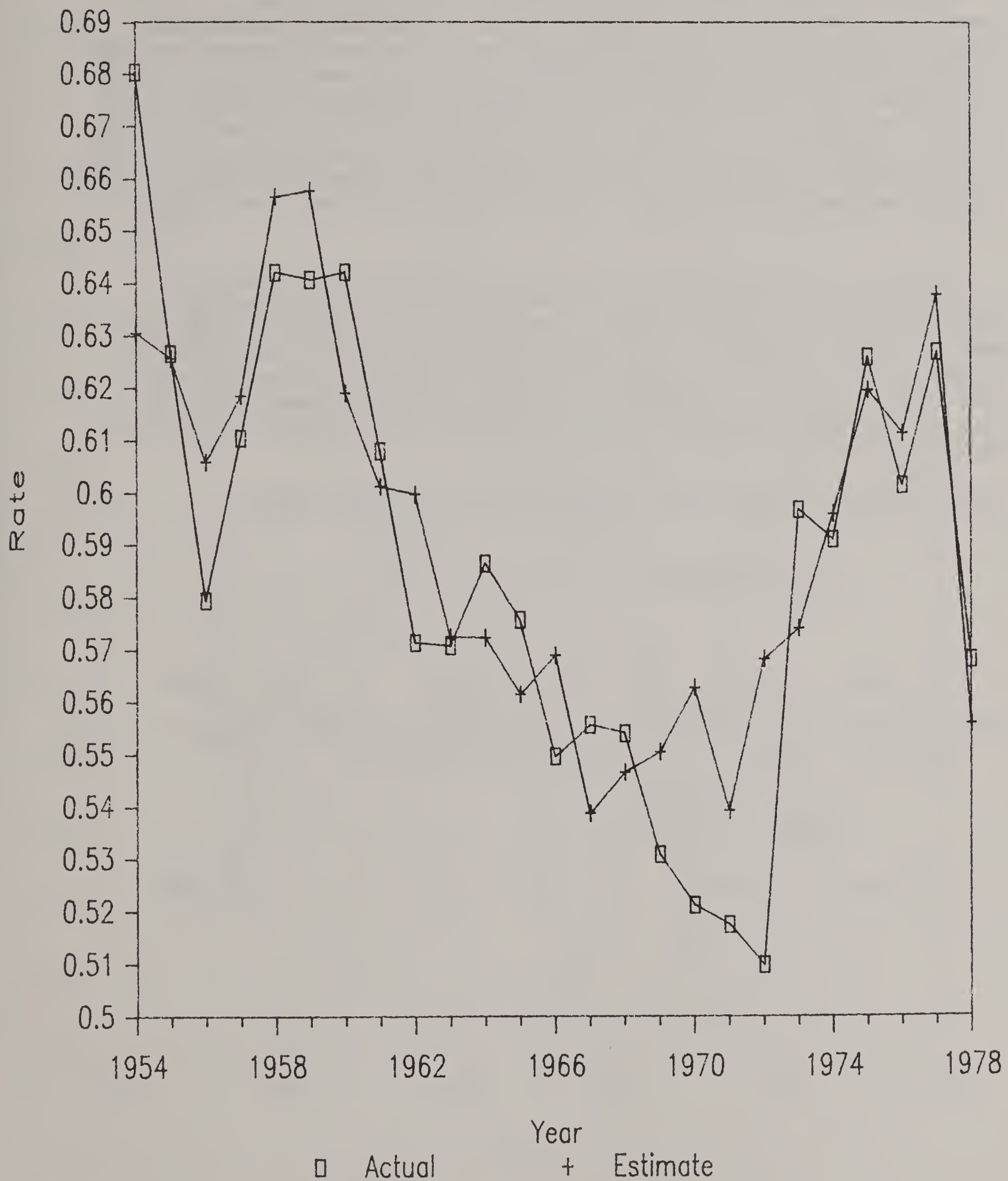


Figure 11--Actual and Estimated Cropland Utilization Rate in the Southern Plains from Equation 20



Northern Plains

Several modifications of the basic approach were necessary to obtain reasonable results for the Northern Plains. Preliminary regressions produced R-squared statistics of less than 0.1 and coefficients with low significance levels and incorrect signs. Results presented below reflect the authors' conviction that (1) the theory summarized by equation (14) does not explain the steady decline in Northern Plains utilization rates during the midfifties, (2) the effective diversion payment rate for wheat does not measure incentives offered to Northern Plains producers, and (3) improper measurements of cost or expected yield precludes use of the expected net returns variable.

Equations (21) and (22) are the best of several preliminary regressions. First, the historical period is 1958-1979. Second, the profitability of crop production is measured by a weighted average of expected prices relative to costs for wheat and barley. Finally, the wheat effective diversion payment rate is replaced by a dummy variable that takes a value of 1 during the acreage-idling programs during the sixties and early seventies. Plots of actual and estimated utilization rates are shown in figures (12) and (13).

$$\begin{aligned} \text{UNP} = & 0.59879 + 0.51071 \text{ PENP} - 0.06657 \text{ DGOV} - 0.013306 \text{ COFNP} & (21) \\ & (13.42) \quad (2.78) \quad (-7.90) \quad (-2.31) \\ & + 0.05966 \text{ PERYNP} \\ & (2.78) \end{aligned}$$

$$R^2 (\text{Adj}) = 0.765 \qquad \text{D.W.} = 2.15 \qquad S = 0.01627$$

$$\begin{aligned} \text{UNP} = & 0.59135 + 0.60065 \text{ PENP} - 0.066823 \text{ DGOV} - 0.629302 \text{ COFNP/LNP} & (22) \\ & (12.72) \quad (1.79) \quad (-7.66) \quad (-1.97) \\ & + 0.061905 \text{ PERYNP} \\ & (2.80) \end{aligned}$$

$$R^2 (\text{Adj}) = 0.749 \qquad \text{D.W.} = 2.09 \qquad S = 0.0168$$

Figure 12--Actual and Estimated Utilization Rate in the Northern Plains from Equation 21

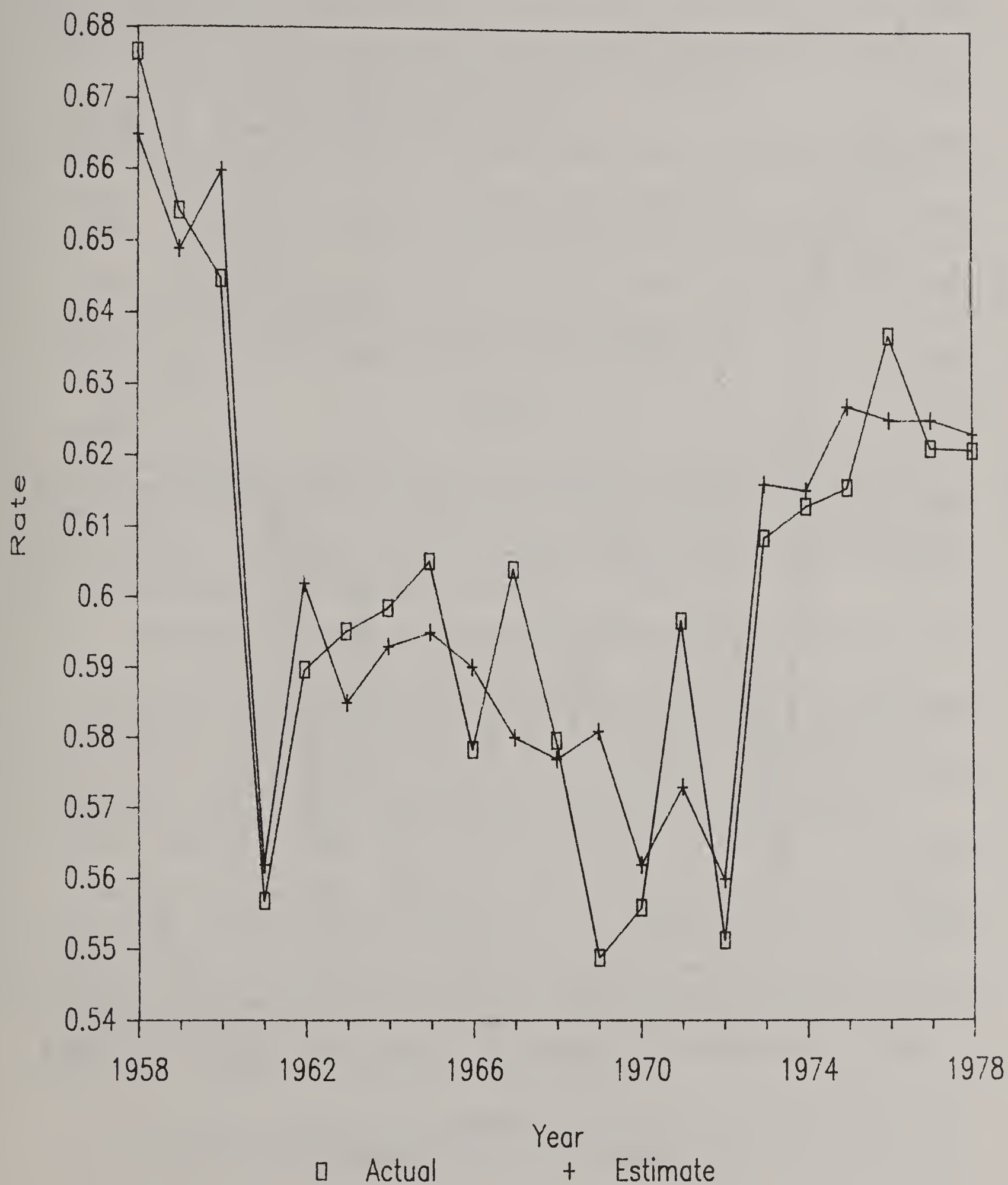
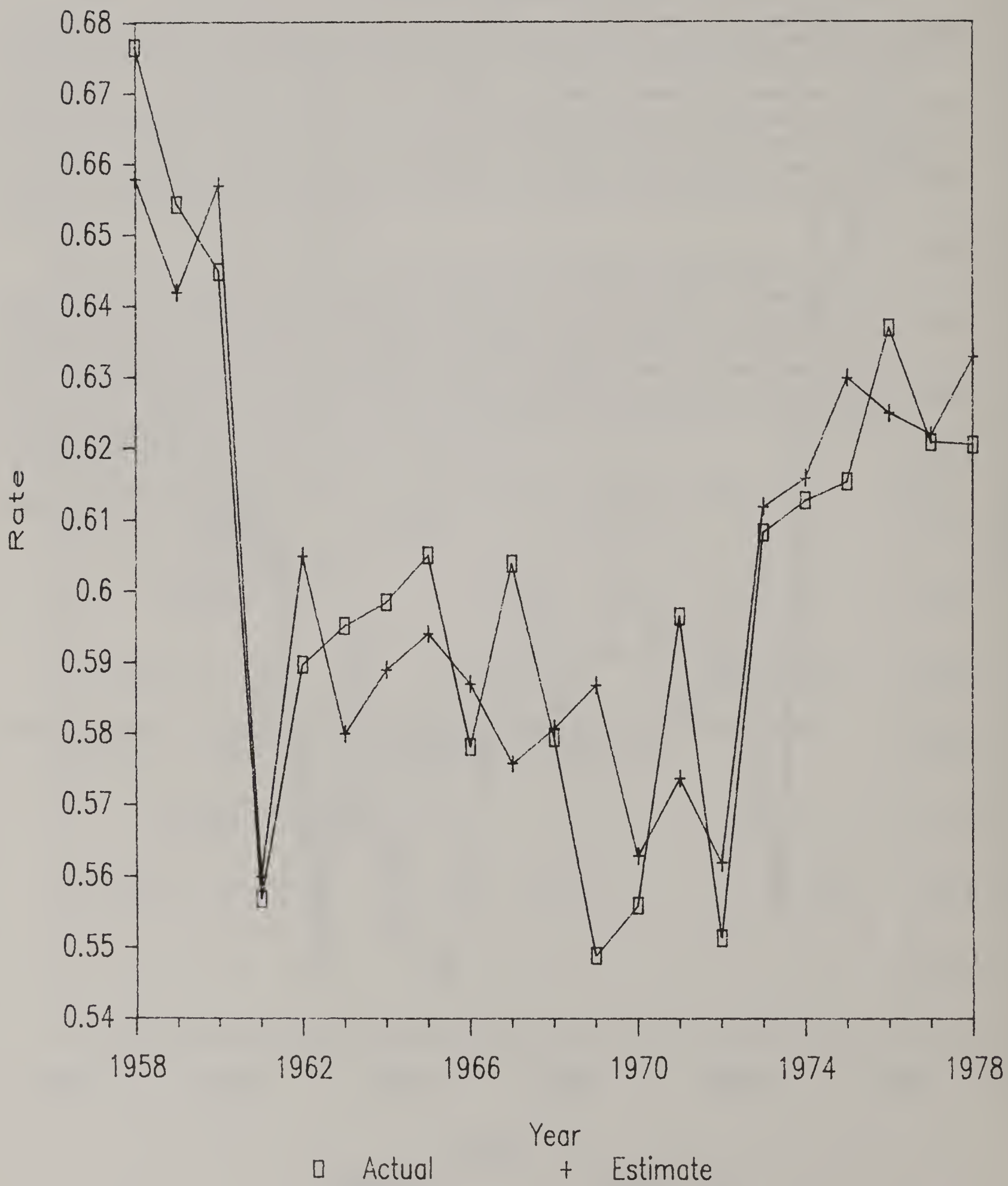


Figure 13--Actual and Estimated Utilization Rate in the Northern Plains from Equation 22



where: $PENP = 0.816 \text{ WHEPE/WHECVNP} + 0.184 \text{ BARPE/BARCV}$,

Dependent variable mean: 0.6034

Historical period: 1958 to 1979

Variable definitions:

UNP is cropland utilization rate in the Northern Plains; area harvested divided by total cropland (percent),
WHEPE is expected wheat price (\$/bu),
BARPE is expected barley price (\$/bu),
WHECVNP is variable cost of producing wheat in the Northern Plains (\$/acre),
BARCV is variable cost of producing barley (\$/acre),
COFNP is cattle on farms in the Northern Plains on January 1 (mil head),
PERYNP is ratio of actual yield to "trend yield" in the Northern Plains (percent),
DGOV is one from 1961 to 1971, zero otherwise, and
LNP is Northern Plains cropland (mil acres).

Summary

Estimated effects of changes in crop prices, cattle population, and effective diversion payment rates on cropland utilization rates are summarized in table 4. The price effect on the cropland utilization rate is largest in the Delta. The cattle population effect is the largest in the Corn Belt. Effective diversion payment rates have more of an impact on Corn Belt and Delta utilization rates.

ESTIMATES OF PLANTED ACREAGE RESPONSE FOR MAJOR FIELD CROPS

The amount of U.S. cropland planted to each crop depends on the expected price (or profitability) of the alternative crops and the amount of land used in the production of all crops. Two specifications are presented in this section. Under the first, cropland planted responds to changes in expected prices of alternative crops deflated by their respective variable cost of production. Under the second, cropland planted responds to changes in the net returns of alternative crops.

The land-in-production variable for each crop is defined according to its primary production region (table 3). Any regional statement of the cropland base for a particular commodity will not be perfect since some of the crop will be produced outside the region. As long as this slippage is kept at a reasonable level though, statistical relations between acreage planted to a crop across the United States and regional land bases might be sufficient. This results in the following definitions of land in production (see table 3):

- (1) For corn, the land-in-production variable is defined as the area planted to all crops in the Corn Belt.

Table 4--Effect of selected changes on cropland utilization rates

Region	Change					
	Crop 1/ prices (\$/unit)	Cattle 2/ population (head)	Effective diversion payment rates 3/			
			Corn (\$/bu)	Sorghum (\$/bu)	Wheat (\$/bu)	Cotton (\$/cwt)
			<u>Percent</u>			
Corn Belt (Eqn 16)	0.0010	-0.9920	-0.3718	0	0	0
Northern Plains (Eqn 22)	.0046	-.6290	0	0	0	0
Southern Plains (Eqn 20)	.0174	-.4780	-.0260	-.0231	-.0332	-.1402
Delta (Eqn 18)	.0266	-.343	0	0	0	-.3429

1/ A 10-percent increase in all crop prices.

2/ A head-per-acre increase.

3/ A 10-percent increase.

- (2) The land-in-production variable for soybeans is defined as the area planted to all crops in the Corn Belt and Delta.
- (3) The land-in-production variable for wheat is defined as the area planted to all crops in the Northern Plains, Southern Plains, and West Coast.
- (4) The land-in-production variable for sorghum is defined as the area planted to all crops in the Southern Plains.
- (5) The land-in-production variable for barley is defined as the area planted to all crops in the Northern Plains and West Coast.
- (6) For oats, the land-in-production variable is defined as the area planted to all crops in the United States.

Corn Acreage Response

Estimates of corn acreage response for the United States specified soybeans as the major competitive crop and the previously defined Corn Belt served as the land base. Straightforward estimation gave satisfactory results. Additionally, a price risk variable had the correct sign and improved the R-squared statistic. Equation (23)

features expected prices relative to variable costs for corn and soybeans while (24) is an analogous specification with expected net returns for the competitive crops. Actual and estimated acreage levels for these equations are shown in figures 14 and 15, respectively.

$$\text{CORAP} = - 7.9047 + 363.40 \text{ CORPE/CORCV} - 121.74 \text{ SOYPE/SOYCV} - \quad (23)$$

(-0.55) (2.45) (-2.79)

$$1.8406 \text{ CORRIS} + 0.57739 \text{ APRCB}$$

(0.94) (6.37)

$$R^2 \text{ (Adj)} = 0.913$$

$$\text{D.W.} = 1.64$$

$$S = 2.07$$

$$\text{CORAP} = -20.379 + 0.19725 \text{ CORNR} - 0.16731 \text{ SOYNR} - 5.5829 \text{ CORRIS} \quad (24)$$

(3.44) (-3.47) (-2.12)

$$+ 0.64727 \text{ APRCB}$$

(10.62)

$$R^2 \text{ (Adj)} = 0.969$$

$$\text{D.W.} = 1.83$$

$$S = 1.91$$

Dependent variable mean: 73.35

Historical period: 1954 to 1978

Variable definitions:

CORAP is area planted to corn, total United States (mil acres),

CORPE is expected corn price (\$/bu),

SOYPE is expected soybean price (\$/bu),

CORCV is variable cost of producing corn (\$/acre),

SOYCV is variable cost of producing soybeans (\$/acre),

APRCB is area planted to principal crops in major corn producing region: Corn Belt (mil acres),

CORRIS is corn price risk (\$/bu),

CORNR is expected net return per acre planted to corn (\$/acre), and

SOYNR is expected net return per acre planted to soybeans (\$/acre).

Soybean Acreage Response

Soybean acreage response estimates specified corn and cotton as the principal competitive crops while the area planted to principal crops in the Corn Belt and Delta was the acreage variable. Again, alternative specifications compared prices relative to costs with net returns. A soybean price risk variable was initially included in the analysis. However, it did not prove to be statistically significant.

Equations (25) and (26) confirm the hypothesis that changes in farmers' habits, as well as fluctuations in crop prices, accounted for the historical variation in soybean acreage. Both of these equations

Figure 14--Actual and Estimated Corn Planted Area From Equation 23

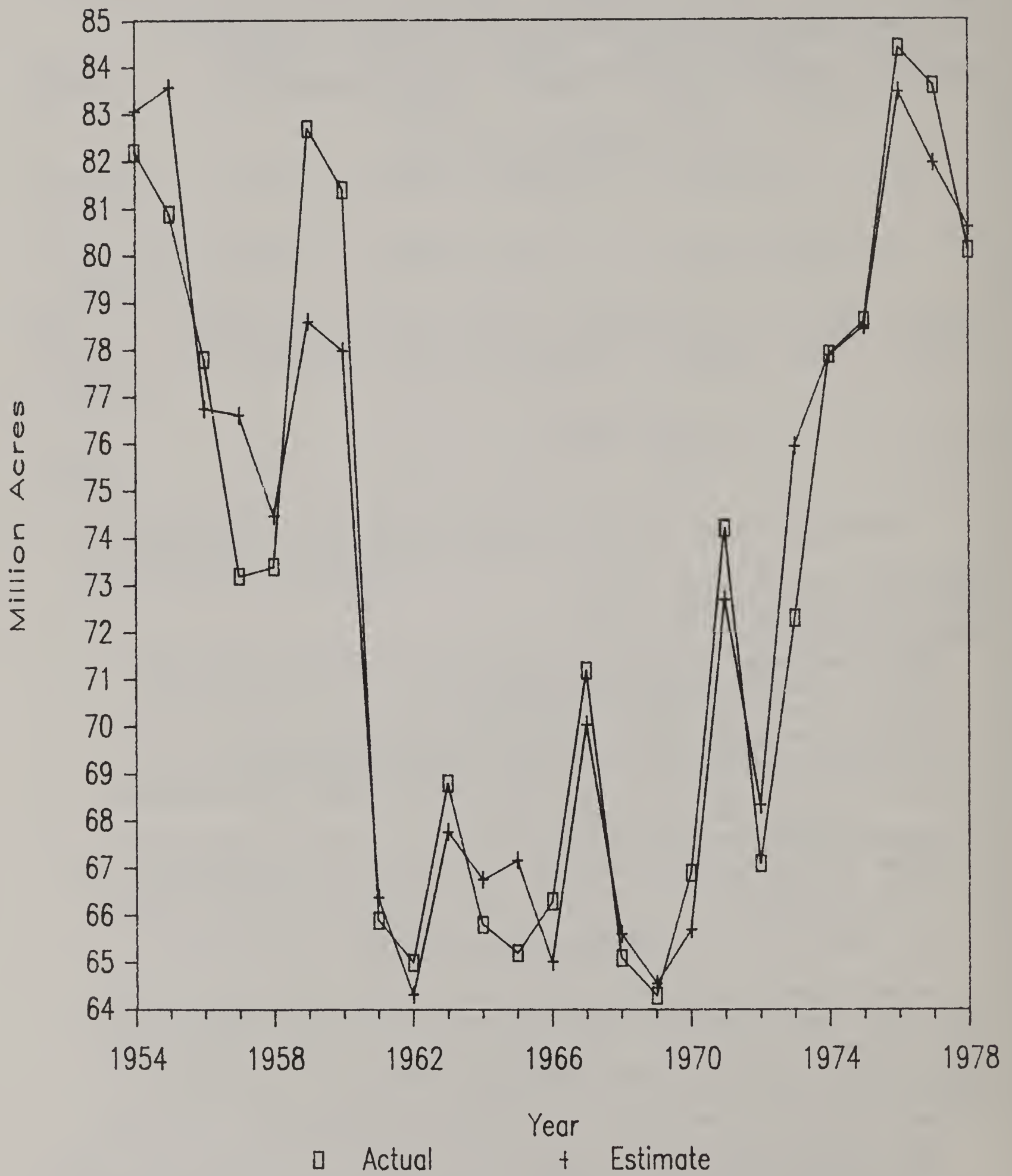
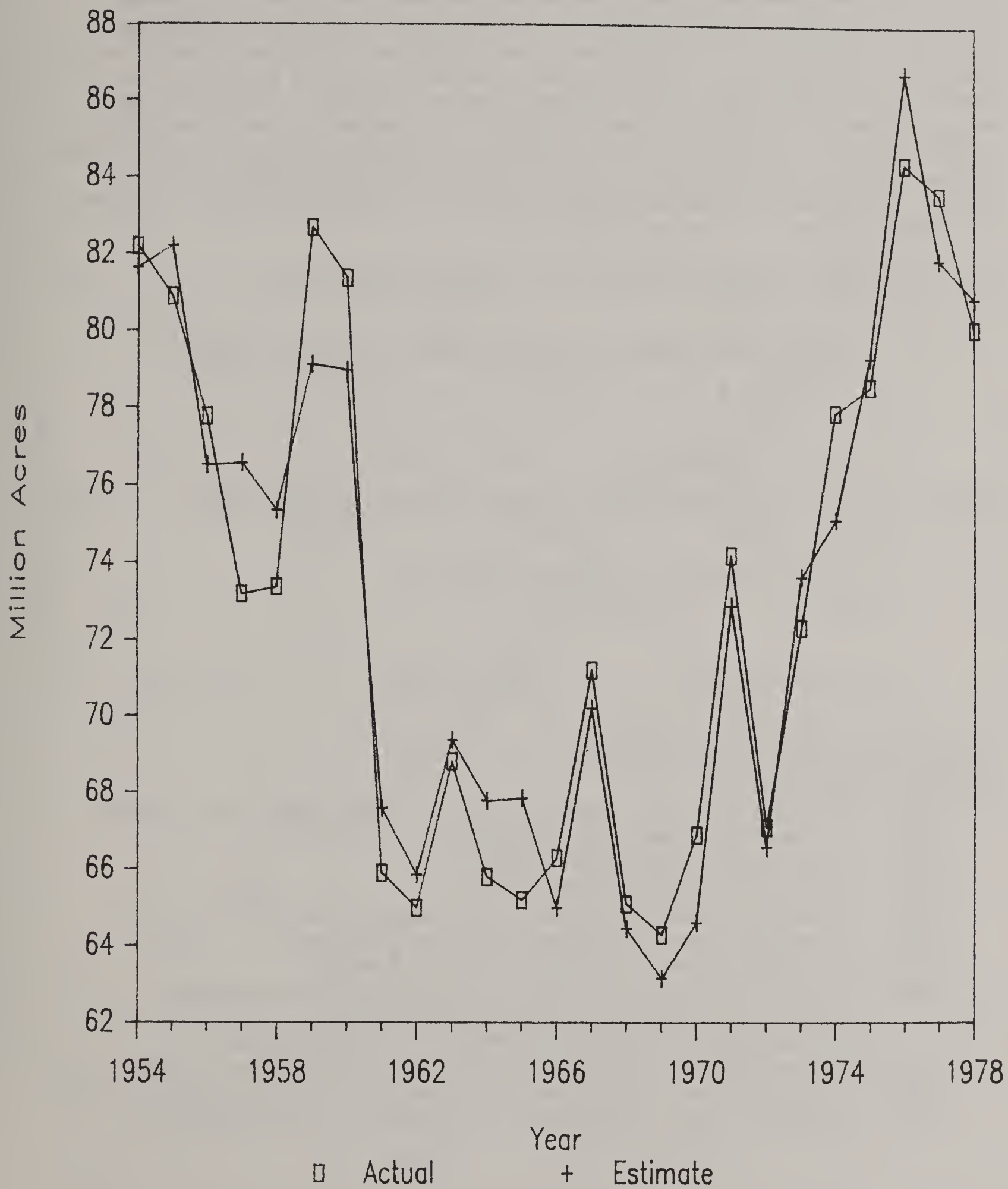


Figure 15--Actual and Estimated Corn Planted Area from Equation 24



have a cross-product term, total acreage planted times trend, to account for the fact that an increase in the total amount of land planted would result in progressively larger soybean plantings over time. In equation (25), for example, an increase of 1 million acres planted to principal crops in 1954 would have resulted in an additional 0.163 million acres of soybeans. Meanwhile, a 1-million-acre increase in 1978 total area would result in an additional 0.36 million acres of soybeans. Equation (26) suggests smaller soybean acreage response to changes in total land area; a 1-million-acre change in area planted to principal crops would increase soybean area by 0.066 million acres in 1954 and 0.21 million acres in 1978. Actual and estimated acreage levels for these equations are shown in figures 16 and 17, respectively.

$$\text{SOYAP} = 2.1145 + 92.898 \text{ SOYPE/SOYCV} - 2862.30 \text{ COTPE/COTCV} \quad (25)$$

(0.13) (1.64) (-2.54)

$$- 384.66 \text{ CORPE/CORCV} + 0.16321 \text{ APRCBD} + 0.008107 \text{ APRCBD} \cdot T$$

(-1.65) (1.87) (8.32)

$$R^2 \text{ (Adj)} = 0.973 \quad \quad \quad \text{D.W.} = 1.83 \quad \quad \quad S = 2.23$$

$$\text{SOYAP} = 5.6126 + 0.22596 \text{ SOYNR} - 0.078931 \text{ COTNR} - 0.17320 \text{ CORNR} \quad (26)$$

(0.756) (5.81) (-4.63) (-5.12)

$$+ 0.06581 \text{ APRCBD} + 0.008891 \text{ APRCBD} \cdot T$$

(10.14) (19.30)

$$R^2 \text{ (Adj)} = 0.990 \quad \quad \quad \text{D.W.} = 2.02 \quad \quad \quad S = 1.38$$

Dependent variable mean: 38.734

Historical period: 1954 to 1978

Variable definitions:

SOYAP is area planted to soybeans, total United States (mil acres),
 SOYPE is expected soybean price (\$/bu),
 COTPE is expected cotton price (\$/cwt),
 CORPE is expected corn price (\$/bu),
 SOYCV is variable cost of producing soybeans (\$/acre),
 COTCV is variable cost of producing cotton (\$/acre),
 CORCV is variable cost of producing corn (\$/acre),
 APRCBD is area planted to principal crops in soybean producing
 regions: Corn Belt and Delta (mil acres),
 T is trend (0 in 1954, 1 in 1955, . . . , 24 in 1978),
 SOYNR is expected net return per acre planted to soybeans (\$/acre),
 COTNR is expected net return per acre planted to cotton (\$/acre), and
 CORNR is expected net return per acre planted to corn (\$/acre).

Figure 16--Actual and Estimated Soybean Planted Area from Equation 25

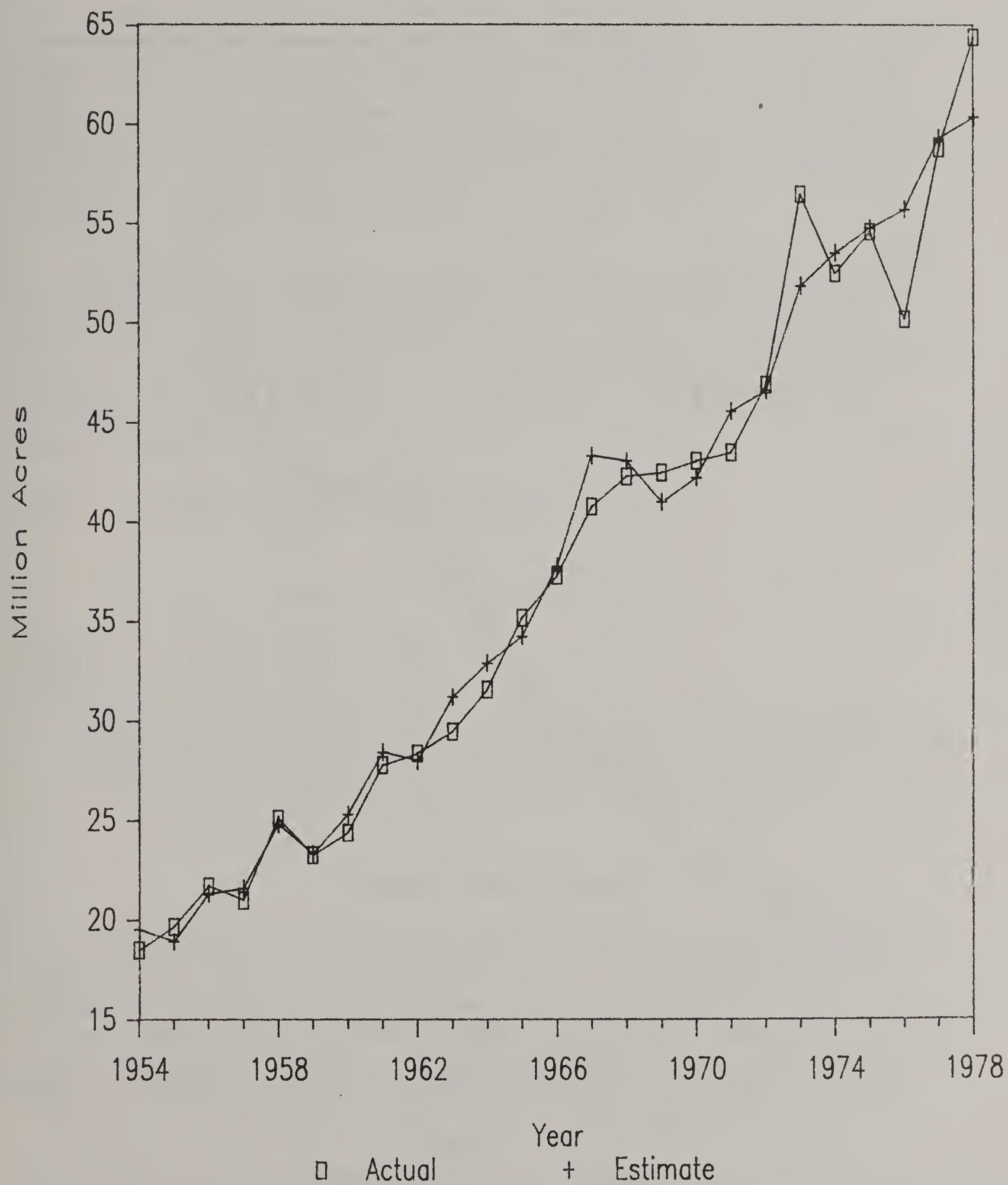
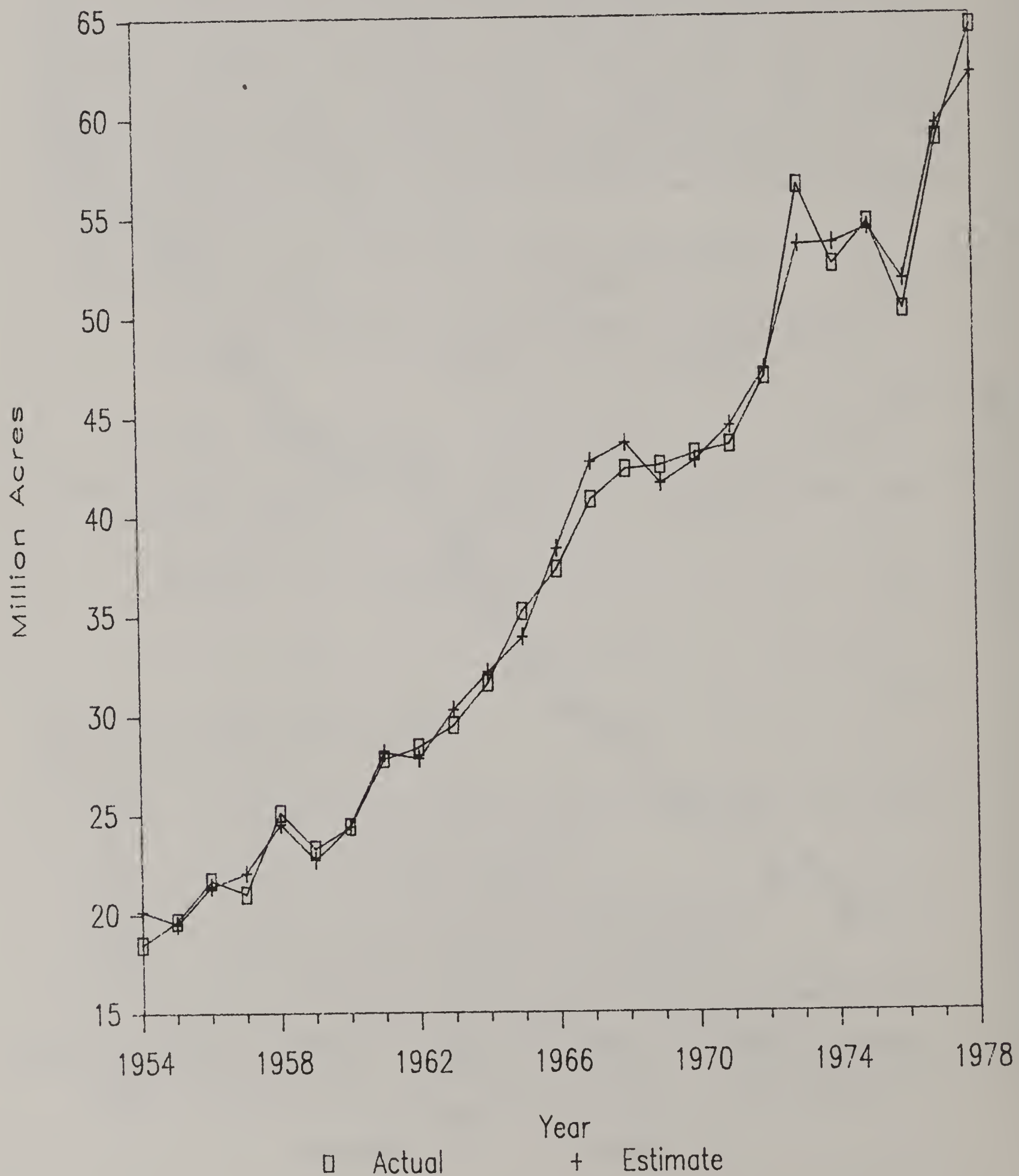


Figure 17--Actual and Estimated Soybean Planted Area from Equation 26



Wheat Acreage Response

Preliminary analysis involved experimentation with a variety of land-in-production variables, competitive crop effects, and the comparison of net returns per acre and prices relative to costs. The prices-relative-to-cost approach consistently showed a negative planted acreage response to increases in expected wheat price. Including the Corn Belt in the land-in-production variable reduced the R-squared statistic in comparison with the result with the three major wheat production regions. When prices or returns for competitive crops were included, t-statistics were typically less than 1.0.

Equation (27) suggests that expected returns in wheat production and the area planted to principal crops in the Great Plains and West Coast are the only systematic determinants of U.S. wheat acreage.^{9/} Both explanatory variables are significant at any reasonable confidence level. And while the R-squared statistic is not high, the Durbin-Watson statistic does not suggest that any systematic influences have been excluded. Actual and estimated acreage levels for this equation are shown in figure 18.

$$\text{WHEAP} = -33.769 + 0.52187 \text{ WHENR} + 0.73551 \text{ APRWB} \quad (27)$$

(-2.45) (6.93) (5.90)

$$R^2 (\text{Adj}) = 0.790$$

$$\text{D.W.} = 2.02$$

$$S = 3.87$$

Dependent variable mean: 59.64

Historical period: 1954 to 1978

Variable definitions:

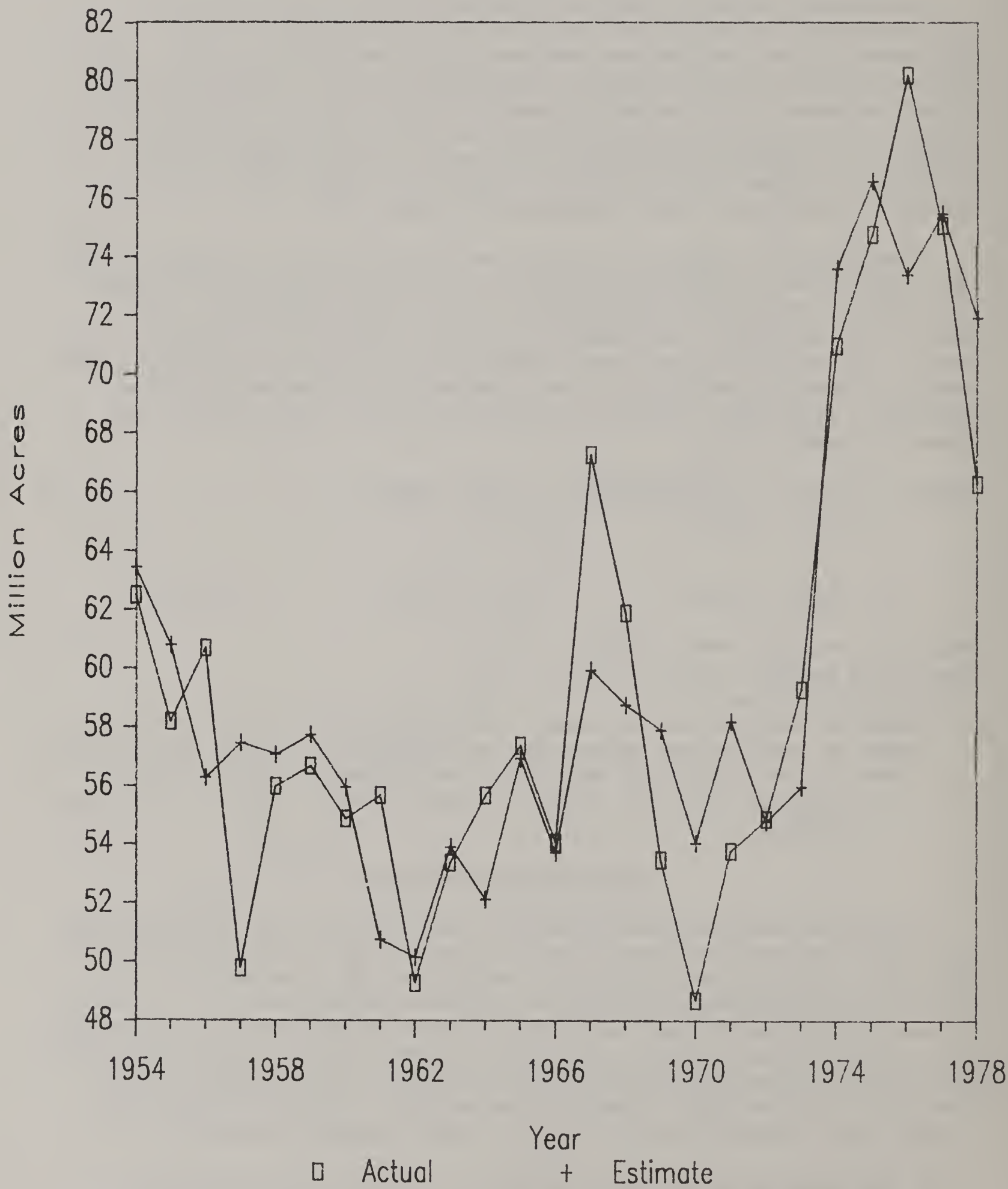
WHEAP is area planted to wheat, total United States (mil acres),
WHENR is expected net returns per acre planted to wheat (\$/acre), and
APRWB is area planted to principal crops in major wheat production
regions: Northern Plains, Southern Plains, and West Coast (mil
acres).

Sorghum Acreage Response

Sorghum acreage response estimates specified corn and cotton as the principal competitive crops while the area planted to principal crops in the Southern Plains was the acreage variable. The R-squared for a variety of preliminary estimates was in the neighborhood of 0.3 because of one outlier in 1961 and also because there is no trend in sorghum area over the historical period. However, t-values indicate significance for individual explanatory variables and almost all turning points were predicted in this highly volatile time series. Hence, the following results seem satisfactory in spite of a low R-squared statistic.

^{9/} The land-in-production data shown in table 2 is computed with harvested acreage for winter wheat. Total U.S. winter wheat abandonment was added to the land-in-production variable reported here.

Figure 18--Actual and Estimated Wheat Planted Area from Equation 27



Omission of the outlier observation (1961) increased the R-squared to about 0.7 without changing t-values or coefficient estimates dramatically.

Equation (28) confirms the hypothesis that changes in farmers' habits, as well as price fluctuations in crop prices, accounted for the historical variation in sorghum acreage. This equation has a cross-product term, total acreage planted times trend, to account for the fact that increases in the total amount of land planted result in progressively smaller increases in sorghum plantings over time. For example, an increase of 1 million acres planted to principal crops in 1958 would have resulted in an additional 0.32 million acres of sorghum. Meanwhile, a 1-million-acre increase in 1978 total area would have resulted in an additional 0.132 million acres of sorghum. Actual and estimated acreage levels for this equation are shown in figure 19.

$$\begin{aligned} \text{SORAP} = & 3.09203 + 0.14458 \text{ SORNR} - 0.05972 \text{ COTNR} - 0.05235 \text{ CORNR} & (28) \\ & (0.496) \quad (1.82) \quad (-2.94) \quad (-1.51) \\ & + 0.32038 \text{ APRSP} - 0.00242 \text{ APRSP} \cdot T \\ & (3.03) \quad (-1.31) \end{aligned}$$

$$R^2 (\text{Adj}) = 0.336$$

$$\text{D.W.} = 2.18$$

$$S = 1.32$$

Dependent variable mean: 17.713

Historical period: 1958 to 1978

Variable definitions:

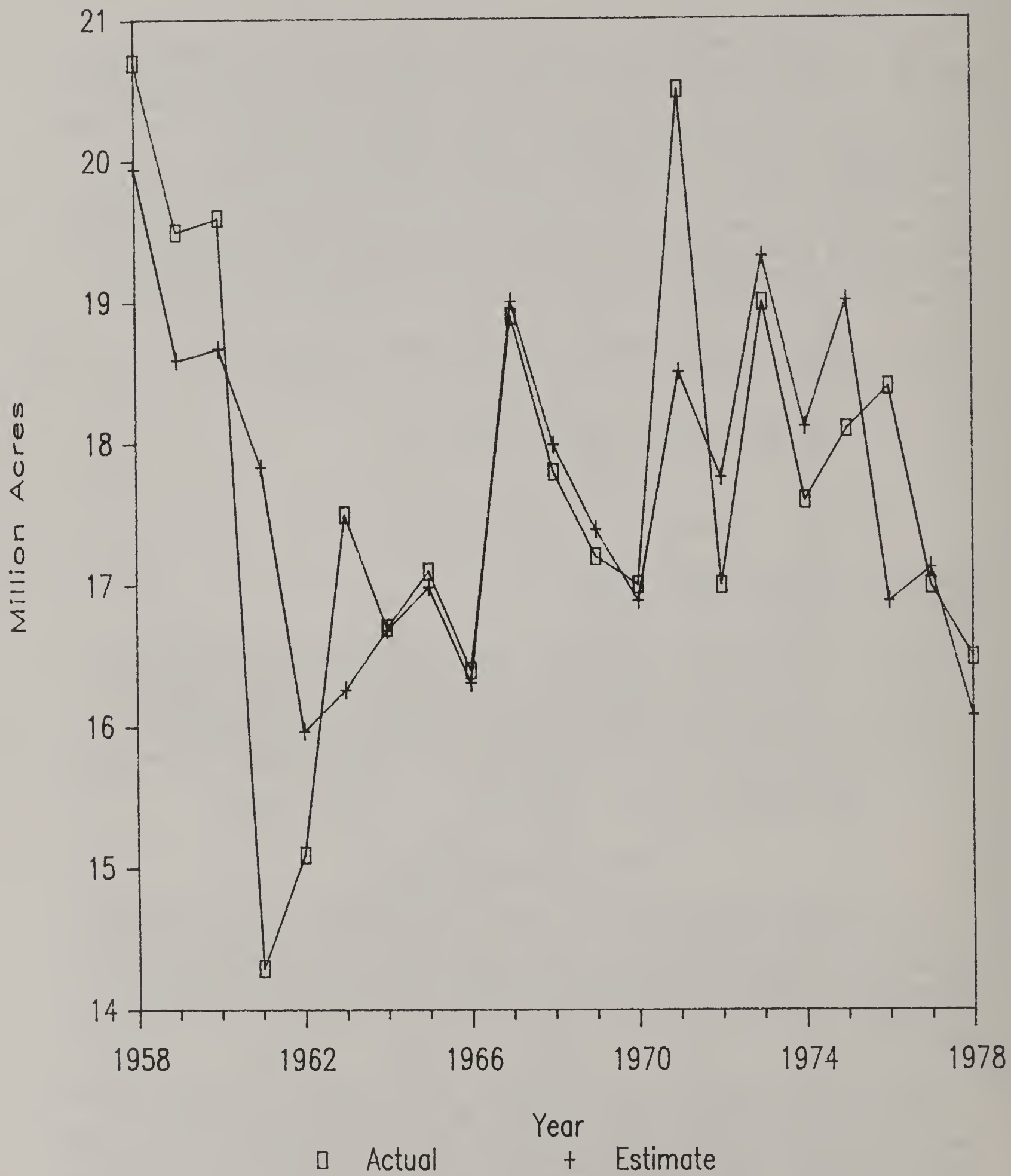
SORAP is area planted to sorghum, total United States (mil acres),
 SORNR is expected net return per acre planted to sorghum (\$/acre),
 COTNR is expected net return per acre planted to cotton (\$/acre),
 CORNR is expected net return per acre planted to corn (\$/acre),
 APRSP is area planted to principal crops in the Southern Plains (mil acres), and
 T is trend (0 in 1954, 1 in 1955, . . . , 24 in 1978)

Oat Acreage Response

Oat acreage response estimates specified soybeans, corn, and wheat as the principal competitive crops while the area planted to principal crops in the United States was the acreage variable. Regressions emphasizing soybean or corn substitutions yielded correct signs but R-squared and t-statistics were better when only wheat substitution was included.

Equation (29) confirms the hypothesis that changes in farmers' habits, as well as fluctuations in net returns, accounted for the historical variation in oat acreage. This equation has a cross-product term, total acreage planted times the natural log of trend, to account for the fact that an increase in the total amount of cropland planted would result in smaller oat plantings over the historical period. For example, an

Figure 19--Actual and Estimated Sorghum Planted Area from Equation 28



increase of 1 million acres planted to principal crops in 1954 would have resulted in an additional 0.105 million acres of oats. Meanwhile, a 1-million-acre increase in 1978 total area would have resulted in only an additional 0.026 million acres of oats. Actual and estimated acreage levels for this equation are shown in figure 20.

$$\begin{aligned} \text{OATAP} = & 16.4270 + 0.24200 \text{ OATNR} - 0.297337 \text{ WHENR} + & (29) \\ & (1.57) \quad (1.25) \quad (-2.79) \\ & 0.10490 \text{ APRUS} - 0.024637 \text{ APRUS} \cdot \ln(T+1) \\ & (3.58) \quad (-6.66) \end{aligned}$$

$$R^2 (\text{Adj}) = 0.946$$

$$\text{D.W.} = 1.18$$

$$S = 2.27$$

Dependent variable mean: 27.376

Historical period: 1954 to 1978

Variable definitions:

- OATAP is area planted to oats, total United States (mil acres),
- OATNR is expected net return per acre planted to oats (\$/acre),
- WHENR is expected net returns per acre planted to wheat; weighted average of previous 2 years by 2/3 and 1/3, respectively (\$/acre),
- APRUS is area planted to principal crops in the United States, 37 States (mil acres), and
- T is trend (0 in 1954, 1 in 1955, . . . , 24 in 1978).

Barley Acreage Response

Barley acreage response estimates specified wheat as the principal competitive crop while the area planted to all crops in the Northern Plains and on the West Coast was the acreage variable. The hypothesis that changes in farmers' habits affected acreage was again tested with the cross-product term, total acreage planted times trend.

The cross-product term suggests that by the end of the historical period, growers tended to devote little additional acreage to barley. In equation (30), for example, an increase of 1 million acres planted to principal crops in 1958 would have resulted in an additional 0.208 million acres of barley. Meanwhile, a 1-million-acre increase in 1978 total area would have resulted in only an additional 0.060 million acres of barley. Actual and estimated acreage levels for this equation are shown in figure 21.

Figure 20--Actual and Estimated Oat Planted Area from Equation 29

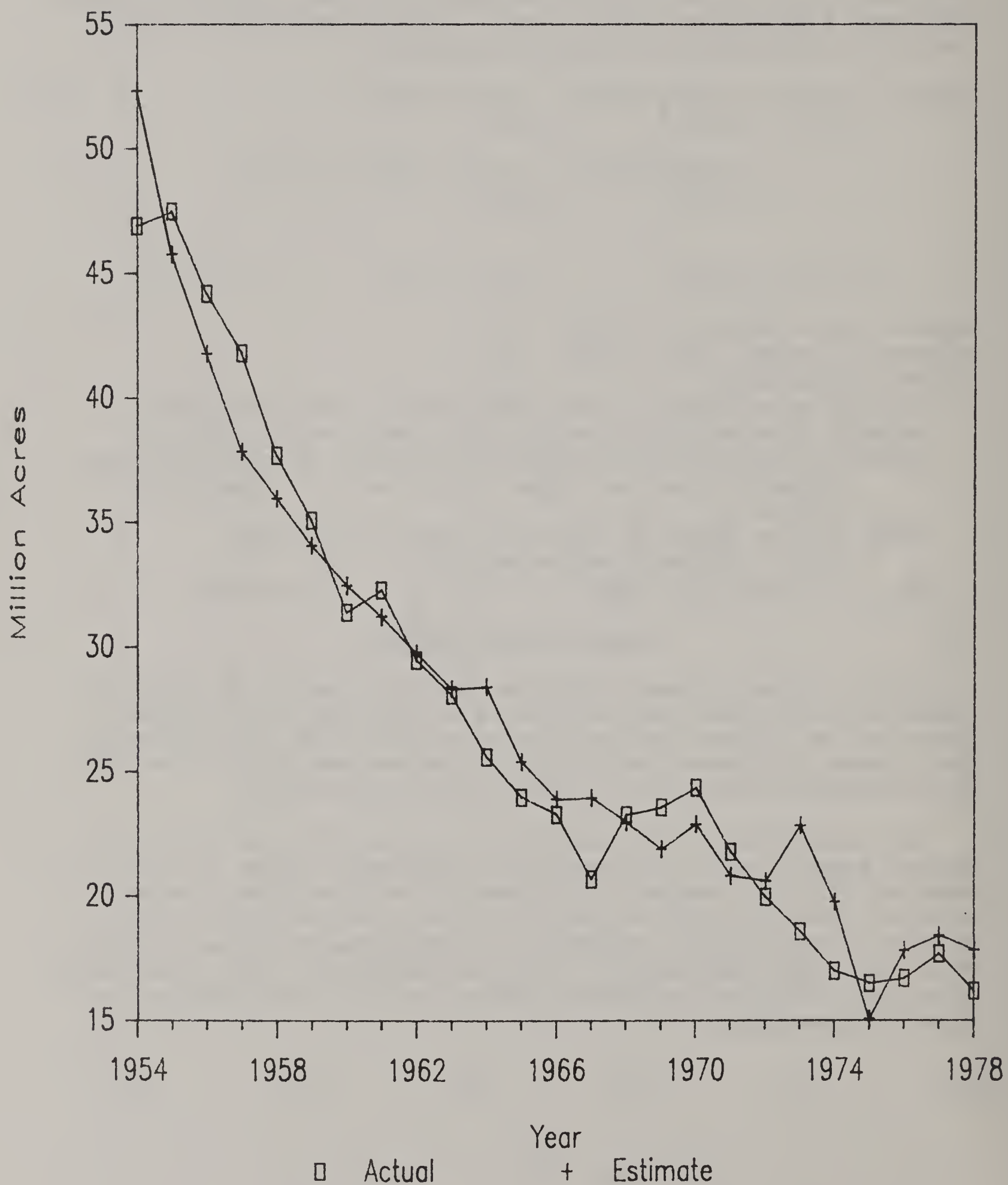
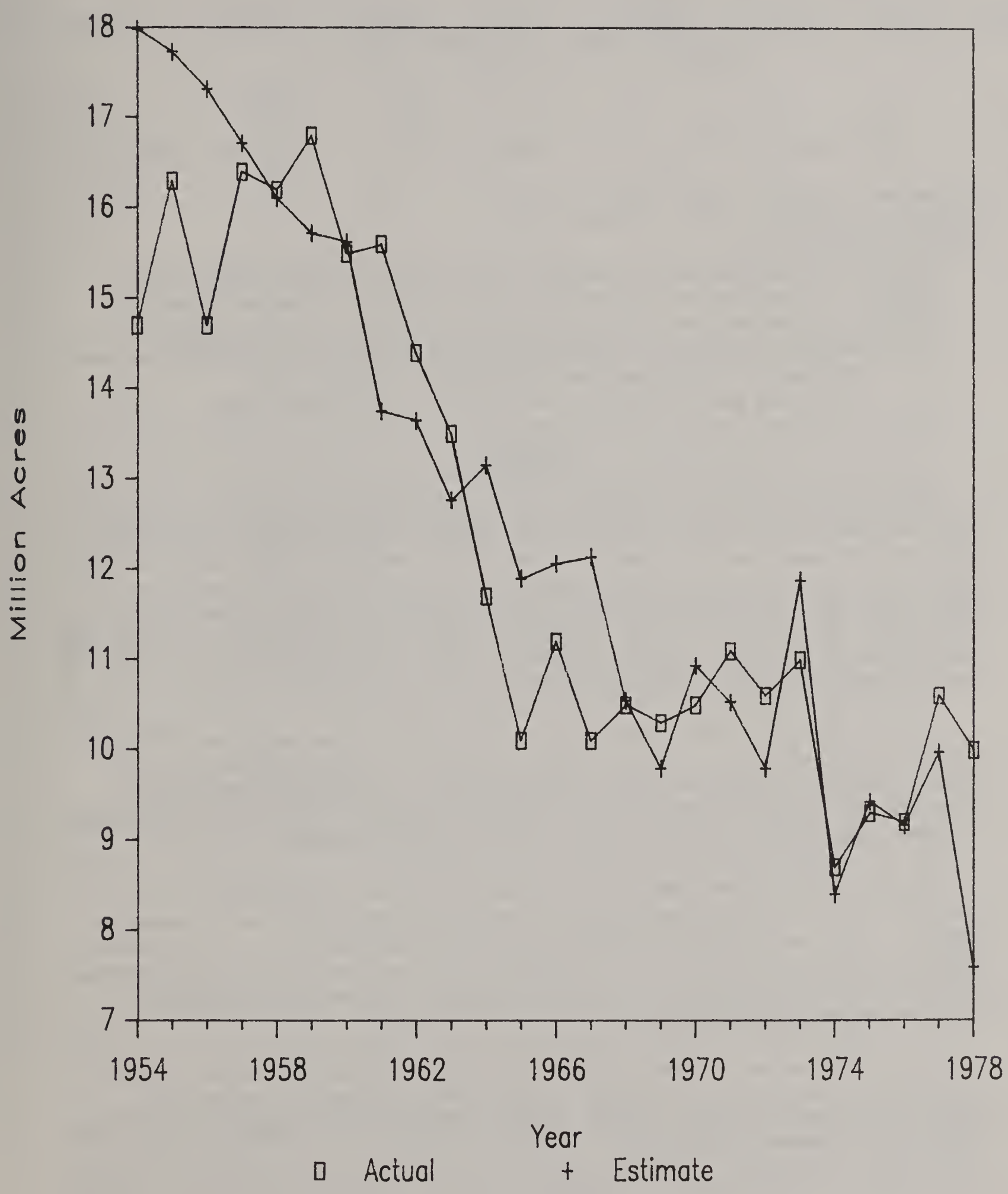


Figure 21--Actual and Estimated Barley Planted Area from Equation 30



$$\begin{array}{rcl} \text{BARAP} = 7.7249 + 0.0992147 \text{ BARNR} - 0.141458 \text{ WHENR} & & (30) \\ (1.07) & (2.05) & (-3.05) \end{array}$$

$$\begin{array}{rcl} + 0.23767 \text{ APBAR} - 0.007386 \text{ APBAR} \cdot T & & \\ (1.47) & & (-5.05) \end{array}$$

$$R^2 (\text{Adj}) = 0.806$$

$$D.W. = 1.32$$

$$S = 1.09$$

Dependent variable mean: 11.74

Historical period: 1958 to 1978

Variable definitions:

BARAP is area planted to barley, total United States (mil acres),
 BARNR is expected net return per acre planted to barley (\$/acre),
 WHENR is expected net return per acre planted to wheat (\$/acre),
 APBAR is area planted to principal crops in barley producing regions:
 Northern Plains and West Coast (mil acres), and
 T is trend (0 in 1954, 1 in 1955, . . . , 24 in 1978).

Summary

This section contains a test of an unconventional method of acreage response estimation; the effects of government set-aside or diversion programs are measured indirectly through the amount of land used in the production of all crops. The results seem to confirm the usefulness of this approach. The estimated relations explain a high proportion of the historical variation in corn, soybean, wheat, barley, and oat acreage and the estimated coefficients of land-in-production variables are in the sensible range between zero and unity.

The use of net returns per acre instead of prices relative to costs improves the results. R-squared and t statistics were higher for net return specifications for corn and soybeans. A positive wheat price response was obtained with the net returns method, while prices relative to costs produced a negative sign for the price estimate.

The approach taken here was to relate national acreage for commodities to area planted to principal crops in a dominant production region. This approach produced satisfactory results for corn, soybeans, sorghum, barley, and oats. If estimates of local substitutions for wheat were required, however, it would be necessary to estimate regional acreage response functions.

Given the market strength specification of expected prices, price elasticities will vary according to the levels of market prices and effective support payment rates. Prices elasticities computed with 1978 data are presented in table 5.

Table 5--Price elasticities of acreage response, 1978 data

Acreage	Price						
	Corn	Soybean	Wheat	Sorghum	Barley	Oats	Cotton
Corn	0.385	-0.273	0	0	0	0	0
Soybean	-.427	.475	0	0	0	0	-.246
Wheat	0	0	.511	0	0	0	0
Sorghum	-.515	0	0	.705	0	0	-.742
Barley	0	0	-.913	0	1.641	0	0
Oats	0	0	-1.170	0	0	.562	0

EVALUATION OF THE MODEL AND THE NEED FOR FURTHER RESEARCH

During estimation of the model, the regional cropland planted to principal crops was defined as the proportion of area planted to area available in each region. However, prior to simulation of the model, these regional response equations were multiplied through by acreage available (exogenous variable). Thus, simulation of the model results in estimates of regional area planted to principal crops and aggregate area planted to specific crops.

Changes that occur outside of the cropland use market set off a chain reaction of adjustment in total cropland planted in each region and the allocation of the planted area to specific crops. Whereas the effects within individual equations were presented earlier, the concern here is with net effects of exogenous changes as indicated by the system of equations.

The model evaluation is conducted over two periods: a historical period and a prediction period. However, equations in the model were estimated over different time frames. The historical period for the model is defined to be 1958-1978, the estimation period common to each equation in the system. The prediction period is 1979-1982.

Historical Period: Forecast Errors

The mean absolute forecasting error for each endogenous variable is quite low (table 6). Area planted to wheat had the largest mean absolute error at 3.5 million areas, but a percentage error of less than 6. No error was larger than 7 percent.

The actual and estimated percentage changes were also quite low. Only three variables had higher estimated than actual changes. For most of the variables, the actual and estimated percent changes were similar. However, estimated changes for area planted to sorghum may be expected to be less than the actual percentage changes.

Table 6--Mean absolute errors for historical period

Planted acreage	Mean absolute error	Mean absolute percentage error	Mean absolute percentage change	
			Actual	Estimated 1/
	<u>Mil. acres</u>	-----	<u>Percent</u>	-----
Corn Belt	2.021	1.391	2.761	3.142
Delta	.630	3.137	2.807	2.639
Southern Plains	1.618	2.819	3.258	3.253
Northern Plains	.752	2.708	3.410	2.284
Corn	1.851	2.549	5.564	6.097
Sorghum	1.095	.385	8.856	4.109
Barley	.771	6.704	7.123	7.553
Oats	1.132	5.103	6.815	5.568
Wheat	3.504	5.940	8.458	5.864
Soybeans	.981	2.249	7.658	6.440

1/ Estimated = $(P_t - P_{t-1}) / P_{t-1}$, where P_t is predicted value in year t.

Historical Period: Turning Point Errors

There are two types of turning point errors. The first is that a turning point is predicted but none occurs. The second type is that a turning point occurs but none is predicted. There are also two types of correct predictions. One is when a turning point is predicted and it does occur; the other is when no turning point is predicted and none occurs.

The model does well for 3 of the 10 endogenous variables with a high proportion of correctly predicted turning points: area planted to principal crops in the Corn Belt, corn planted area, and soybean planted area (table 7). Five variables (area planted to principal crops in the Delta, Northern Plains, and Southern Plains, sorghum planted area, and wheat planted area) performed the worst. The model's performance might be improved by estimating regional acreage response equations for specific crops and examining the factors considered in the definition of regional area planted to principal crops.

Turning point errors that occur in the estimates of area planted to principal crops may cause turning point errors in area planted to specific crops. Thus, initial attempts to correct for these errors should be concentrated on the estimates of area planted to principal crops in the Great Plains and Delta.

Table 7--Performance statistics for historical period

Planted acreage	Root squared mean relative error	Theil U1 statistic	Theil U2 statistic	Turning point error
Corn Belt	0.021	0.010	0.535	0.143
Delta	.038	.020	1.258	.476
Southern Plains	.035	.017	1.097	.381
Northern Plains	.033	.016	.728	.524
Corn	.030	.015	.520	.143
Sorghum	.079	.037	.837	.476
Barley	.083	.039	1.055	.286
Oats	.067	.028	.798	.238
Wheat	.076	.037	.944	.429
Soybeans	.030	.017	.469	.048

Historical Period: Tests for Bias and Specification Error

Theil has shown that if a linear relationship exists between the predicted (P) and actual values (A), one can improve the forecasts by applying a linear adjustment to the predicted values. The procedure is termed the optional linear correction of the forecasts.

$$A = a + b P \quad (31)$$

According to the tests reported in table 8, this procedure could improve the forecasts for two of the variables (area planted to principal crops in the Delta and Northern Plains).

The mean-squared error (MSE) may be decomposed into three components, each attributed to a particular source of prediction error (Theil);

$$\begin{aligned}
 \text{MSE} &= \sum_{t=1}^n (A_t - P_t)^2 \\
 &= (A - P)^2 + (1 - b)^2 s_p^2 + (s_a - b s_p)^2 \\
 &= \text{BIAS} + \text{SYSTEMATIC} + \text{RANDOM}
 \end{aligned} \quad (32)$$

Table 8--Test for linear relationship between predicted and actual values for historical period

Planted acres	a	t-statistic 1/	b	t-statistic 2/	F-statistic 3/
Corn Belt	2.176	0.172	0.986	-0.159	0.043
Delta	-4.107	-2.568	1.215	2.670	4.006
Southern Plains	4.318	.548	.922	-.584	.361
Northern Plains	5.703	1.976	.787	-2.112	4.779
Corn	-1.895	-.348	1.030	.406	.275
Sorghum	1.856	.375	.883	-.424	.416
Barley	.301	.265	.976	-.256	.036
Oats	.431	.339	.971	-.570	.531
Wheat	4.485	.611	.939	-.498	.497
Soybeans	-.792	-.654	1.023	.790	.387

1/ Test for $a = 0$, critical value of $t(.05,19)$ is 2.093.

2/ Test for $b = 1$, critical value of $t(.05,19)$ is 2.093.

3/ Test for $a=0$ or $b=1$, critical value of $f(.05,2,19)$ is 3.520. It is possible that the F-test be significant while all t-tests are not.

where \bar{A} and \bar{P} are the means and s_a and s_p the standard deviations of actual and predicted observations, respectively. Dividing the above decomposition through by MSE results in a measure of the proportion of total error which may be attributed to each source of error. There is a linkage between this decomposition and the optimal linear correction of forecasts (equation 31). If $a = 0$ in the linear correction, the bias component is zero. If $b = 1$, the systematic component is zero.

For most of the variables, more than 95 percent of the error is attributed to random error (table 9). For area planted to principal crops in the Delta and Northern Plains, only 70 percent of the error is random. For area planted in the Delta, about 25 percent of the error is systematic. For area planted in the Northern Plains, 15 percent of the error is bias and 15 percent is systematic.

Theil's U1 statistic is one measure of a model's predictive ability. The value of this statistic equals zero if the model's estimates for a variable are exactly equal to its historical data. The maximum value of Theil's U1 statistics is 1, which will occur either when negative proportionality exists between the model's estimates and historical data, or the model always predicts a value of zero for nonzero historical values, or when the model predicts nonzero values for historical values that are zero.

Table 9--Decomposition of error of forecast for historical period

Planted acres	Squared mean error	Root squared error of forecast			
		Error	proportion due to--		
			Bias	Systematic	Random
Corn Belt	0.029	3.190	0.003	0.001	0.996
Delta	.020	.825	.030	.255	.715
Southern Plains	.078	2.114	.018	.016	.966
Northern Plains	.147	.941	.165	.152	.682
Corn	.094	2.292	.018	.008	.974
Sorghum	.057	1.381	.030	.009	.961
Barley	0	.991	0	.003	.996
Oats	.073	1.481	.033	.015	.951
Wheat	.742	4.681	.034	.012	.954
Soybeans	.017	1.551	.007	.030	.963

$$U_1 = \frac{\sum_{t=1}^T ((P_t - P_{t-1}) - (A_t - A_{t-1}))^2}{\sum_{t=1}^T (A_t - A_{t-1})^2}$$

Theil's U2 statistic is a more stringent test of the predictive ability. The statistic equals zero when the model's estimates for a particular variable exactly coincide with its historical data. It equals 1 if the forecast's error generated by the model for a variable equals the error generated when we assume the variable remains unchanged from the previous year. A value greater than 1 indicates that the model generates predictive errors exceeding those generated by a no-change model.

$$U_2 = \frac{\sum_{t=1}^T (P_t - \bar{P}_t)}{\sum_{t=1}^T (A_t - A_{t-1})}$$

As noted in table 7, three variables have Theil's U2 statistics exceeding 1. However, the large proportion of turning point errors indicated for area planted in Northern Plains, area planted to sorghum and area planted to wheat, did not lead to substantial prediction errors.

Prediction Period

The statistics reported in tables 10 and 11 indicate that the cropland use model did not perform well over the prediction period. For half of the estimates, the mean absolute percentage error was greater than 10. Furthermore, most errors of forecast in the system are attributed to either bias or systematic error.

A look into the structure of the model reveals that one of the driving forces in the model is the expected-yield assumption. Although the generated expected yields are realistic throughout most of the estimation period, the later year estimates are questionable, particularly for sorghum, barley, and cotton. Further, there is evidence of both systematic error and bias in the generated expectations.

Over the prediction period, there is evidence that the quadratic trend effects are overstated. This caused the expected yields for sorghum, oats, and cotton to decline through time. Finally, cotton yields have a history of alternating good and bad years since 1976, with no real trend in evidence.

The system was solved with the constraint that expected yields were equal to realized yields. Although there was some improvement noted in the mean absolute percentage errors (table 12), there was still a high degree of bias and systematic error in the forecasts (table 13).

Another assumption that merits evaluation is the use of trend to explain the decline of acres planted to sorghum, barley, and oats. Although this might have been true during the sixties and most of the seventies, there is evidence that this is no longer true. Acres planted to these crops have apparently stabilized, and this should be reflected in the specification of the model.

Table 10--Mean absolute errors for prediction period

Planted acreage	Mean absolute error	Mean absolute percentage error	Mean absolute percentage change	
			Actual	Estimated 1/
Corn Belt	5.268	3.102	2.021	2.493
Delta	4.162	14.648	5.174	3.390
Southern Plains	2.497	3.908	2.369	5.772
Northern Plains	1.819	5.369	4.549	1.157
Corn	2.355	2.851	1.534	4.545
Sorghum	3.299	21.338	4.110	7.429
Barley	1.214	12.966	9.868	5.933
Oats	1.811	13.203	6.310	15.451
Wheat	10.468	12.406	8.074	9.715
Soybean	5.036	7.147	5.487	7.025

1/ Estimated = $(P_t - P_{t-1})/P_{t-1}$, where P_t is predicted value in year t.

Table 11--Performance statistics for prediction period

Planted acreage	Squared mean error	Root squared error of forecast			
		Error	proportion due to--		
			Bias	Systematic	Random
Corn Belt	27.748	6.128	0.739	0.185	0.076
Delta	17.321	5.060	.676	.215	.109
Southern Plains	2.501	3.386	.218	.716	.066
Northern Plains	.543	2.914	.064	.150	.786
Corn	.031	2.915	.004	.780	.214
Sorghum	10.883	3.619	.831	.149	.020
Barley	1.081	1.616	.414	.283	.303
Oats	.581	2.246	.115	.862	.023
Wheat	109.576	14.249	.540	.075	.385
Soybeans	2.150	6.385	.053	.819	.129

Table 12--Mean absolute errors for prediction period when expected yields assumed to be equal to realized yields

Planted acreage	Mean absolute error	Mean absolute percentage error	Mean absolute percentage change	
			actual	estimated 1/
Corn Belt	4.990	2.940	2.021	2.515
Delta	3.526	12.295	5.174	7.927
Southern Plains	1.877	2.917	2.369	5.938
Northern Plains	1.937	5.662	4.549	.763
Corn	4.225	5.093	1.534	3.255
Sorghum	4.971	32.069	4.110	16.961
Barley	1.825	19.623	9.868	12.402
Oats	4.132	30.060	6.310	22.838
Wheat	4.204	4.983	8.074	11.921
Soybeans	4.689	6.597	5.487	6.075

1/ Estimated = $(P_t - P_{t-1})/P_{t-1}$, where P_t is predicted value in year t.

Table 13--Performance statistics for prediction period when expected yields assumed to be equal to realized yields

Planted acreage	Squared mean error	Root squared error of forecast			
		Error	Proportion due to--		
			Bias	Systematic	Random
Corn Belt	24.904	5.797	0.741	0.188	0.071
Delta	11.473	4.717	.559	.311	.131
Southern Plains	.258	2.486	.042	.864	.094
Northern Plains	1.217	3.274	.113	.002	.885
Corn	17.850	5.479	.595	.327	.079
Sorghum	22.045	6.297	.556	.438	.006
Barley	2.879	2.281	.553	.294	.153
Oats	11.853	4.783	.518	.475	.007
Wheat	10.407	7.757	.173	.082	.745
Soybeans	12.235	7.574	.213	.697	.090

Results of the evaluation over the prediction period indicate that there has been structural shifts over the latter part of the seventies and early eighties. The estimated system did not approximate these shifts during forecasting. Therefore, estimated relations should be reestimated with new information. Nevertheless, the estimated relations adequately describe operations of the cropland use market over the historical period.

Need for Further Research

Evaluation of the cropland use model over the forecast period indicated that there is much to be done, even though the model performed adequately over the historical period. Estimates revealed that there is a cropland market which significantly affects area planted to specific crops. To ignore effects of this market while formulating an econometric estimator of area planted might contribute to misspecification and lead to biased and inconsistent coefficient estimates. This misspecification would not cause the estimates of area planted to be biased; however, the estimates would be inefficient.

One issue that needs further attention is the concept of land planted to principal crops. One has to initially decide which crops are to be included in the series, and maintain them throughout the study period. Then, one has to decide how to treat crops that are planted in the previous fall such as winter wheat and rye. SRS dealt with this difficulty by using harvested acres for these crops instead of planted acres. Difficulties that arose in analysis of cropland utilization rates in the Great Plains indicate that perhaps this is not appropriate. Additional research is underway to rectify the data deficiency by using "planted acreage" series to principal crops.

Another issue to be addressed is the definition of the production regions. Regions were defined in order to improve results for corn, soybeans, and wheat. This was done because these were the initial commodities considered in the course of this project. However, perhaps it might be preferable to construct the model by the USDA farm production regions. This would make the model more universally applicable to a variety of crops. Further, model results would be more readily understood were they presented in more common terms.

Inasmuch as this is a regional model, planting decisions should be considered on a regional basis. Here, the "effective" policy variables were considered on a national basis. However, farmers' planting decisions are made on the basis of local loan rates. This points to the construction of regional effective policy variables. Related to this point is that an index or weighted average of diversion payments for all relevant crops in a region would be preferred to the payments for a specific crop in estimating cropland planted acreage response.

The inventory of cattle on farms was used as an indicator of the demand for grazing land. This is not a precise measure as that inventory

number includes cattle on feed. A closer approximation of cattle grazed may be obtained by subtracting cattle on feed from the total inventory of cattle on farms. However, as in the measurement of cropland planted to principal crops, livestock inventory data series as reported by SRS have been subject to changes in definition through time. The researcher has to be aware of these and perhaps make adjustments.

Double cropping is an issue which plagues acreage response estimates. Current models do not consider double cropping and they cannot forecast double cropping. The occurrence of double cropping in the Southeast and Delta makes it difficult to assess the effect of changes in cropland because there is no distinction between double crop or single crop acreage. Obviously, a change in double crop acreage has a larger impact on acreage planted than a change in single crop acreage.

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APPENDIX

This appendix documents components of expected net returns variables for major field crops. Computed values of expected returns per acre for major U.S. field crops are shown in appendix table 1.

The equation used to compute expected price is:

$$PE = PS + g [\ln(D + 1)(D + 1) - D], \text{ where}$$

$$D = PML1 - PS,$$

and:

PML1 is market price in previous year for crop i, and
PS is effective support price in current year for crop i.

The coefficient was chosen so that $d(PE)/d(PML1) = 1$ when D reached the maximum value for the 1954 to 1978 period. Also, whenever $D = 0$, D was reset at zero, so that the expected price would not fall below the support floor. g values are:

Corn:	1.0068	Soybeans:	0.5936
Sorghum:	0.9986	Wheat:	0.9972
Barley:	0.9972	Cotton:	0.3367
Oats:	1.4532		

Expected prices for these seven commodities are shown in appendix table 2.

Expected yields (per planted acre) are the estimates from a regression of actual yields on trend (linear and quadratic terms) over the 1954 to 1978 period. The estimated relations are shown below and appendix table 3 shows estimated yields over the 1954 to 1978 period.

Corn:	$CORYE = - 276.88 + 8.35 T - 0.049 T^2$
Sorghum:	$SORYE = - 456.92 + 13.74 T - 0.094 T^2$
Barley:	$BARYE = - 102.54 + 3.36 T - 0.19 T^2$
Oats:	$OATYE = - 100.91 + 3.83 T - 0.026 T^2$
Wheat:	$WHEYE = - 99.71 + 3.32 T - 0.022 T^2$
Soybeans:	$SOYYE = - 38.49 + 1.56 T - 0.009 T^2$
Cotton:	$COTYE = - 1592.6084 + 59.83 T - 0.437 T^2$

Cost data for the 1974-1978 period are taken from cost of production surveys (13). Variable costs include expenditures on seed, chemicals (fertilizer, lime, herbicides, and pesticides) and labor. However, costs

associated with machinery ownership, overhead, management, and land are excluded.

Cost data for individual crops are not readily available prior to 1974. A cost index was developed for each of the major crops; the method is approximate but should capture the trend in production costs. An index of the variable costs associated with the production of crop i (C) are approximated by the product of an index of the price paid for variable production items (P) and the quantity of variable inputs (Q):

$$C = P \cdot Q.$$

The input price index is a weighted average of SRS prices paid indices for seed, fuel, and various classes of fertilizer; the weights for the index are expenditure proportions for these input classes in the production of crop i (5).^{1/} The quantity indices are weighted averages of regional input indices for seed, chemicals, machinery and mechanical power, and labor (12). These component indices measure the quantity of inputs used in production of all agricultural commodities in a particular region. The quantity index associated with a particular commodity was developed by using expenditure proportions from the 1974 cost of production survey and by using regional input indices for a dominant production area. Corn Belt inputs were used for the corn input quantity index, the Southern Plains inputs were used for wheat, and input quantities in the Delta were used for soybeans and cotton.^{2/}

The cost index was adjusted so that 1974 was the base year. Then, dollar per acre estimates for the pre-1974 period were obtained by multiplying the index by the 1974 estimate from the cost of production survey. These data are shown in appendix table 4.

^{1/} Price indices were computed by this method for corn, soybeans, wheat, and cotton. The wheat price index was also used as a proxy for minor grain (sorghum, barley, and oats) input prices.

^{2/} The wheat quantity index was used for oats. Sorghum and barley quantity indices were computed with expenditure proportions from the cost of production summary. The sorghum index is constructed with inputs from the Southern Plains region; the barley index from the Northern Plains region.

Appendix table 1--Expected returns per acre

Year	Corn	Sorghum	Barley	Oats	Wheat	Soybeans	Cotton
<u>Dollars</u>							
1954	5.667	-10.546	3.604	10.002	12.504	26.141	29.452
1955	11.175	-8.936	5.629	7.060	11.528	24.192	39.651
1956	9.023	-3.658	5.956	8.917	11.859	27.432	41.409
1957	10.012	-.360	6.336	8.829	13.834	27.482	48.786
1958	5.155	1.959	3.434	9.077	13.099	28.678	51.551
1959	16.501	1.165	4.558	6.337	13.068	24.759	60.561
1960	17.349	3.126	10.227	7.070	13.926	25.780	57.595
1961	10.412	2.336	3.063	11.019	14.876	35.676	52.338
1962	12.908	4.833	5.151	11.391	15.588	36.065	63.498
1963	14.582	6.939	4.364	12.627	19.744	36.224	56.386
1964	11.707	6.843	5.820	13.127	16.311	36.546	56.366
1965	13.344	8.855	5.159	11.649	22.864	36.930	49.900
1966	3.824	2.721	14.369	11.024	24.908	41.715	44.931
1967	10.763	6.191	14.468	11.133	24.644	41.273	8.051
1968	.912	2.450	4.215	11.154	25.380	41.576	25.761
1969	5.596	4.157	4.301	12.120	27.218	35.980	30.648
1970	7.471	6.233	12.165	12.131	22.573	36.360	36.329
1971	23.567	17.261	14.252	7.945	26.295	36.326	20.663
1972	10.058	11.244	9.398	7.281	23.888	37.028	19.171
1973	18.936	5.976	17.424	3.885	14.763	47.203	3.594
1974	54.307	14.841	28.684	29.715	45.737	65.182	12.381
1975	86.440	36.506	46.127	14.541	48.564	89.446	28.904
1976	57.412	22.684	30.101	13.375	37.421	50.607	47.080
1977	62.268	39.953	44.632	18.510	39.001	92.453	90.808
1978	61.237	21.079	24.861	10.351	26.964	81.683	38.902

Appendix table 2--Expected prices

Year	Corn	Sorghum	Barley	Oats	Wheat	Soybeans	Cotton
<u>Dollars</u>							
1954	1.315	1.278	0.973	0.750	1.791	2.284	0.295
1955	1.335	1.029	1.022	.618	1.611	2.086	.304
1956	1.137	1.103	.940	.650	1.524	2.151	.289
1957	1.010	1.047	.932	.614	1.520	2.092	.284
1958	.889	1.025	.777	.610	1.427	2.090	.271
1959	1.120	.862	.778	.504	1.350	1.856	.302
1960	1.060	.851	.930	.515	1.341	1.853	.287
1961	.852	.759	.667	.620	1.340	2.300	.275
1962	.871	.785	.713	.620	1.333	2.250	.295
1963	.907	.810	.680	.650	1.483	2.252	.282
1964	.851	.757	.655	.650	1.293	2.269	.281
1965	.869	.776	.602	.601	1.530	2.286	.258
1966	.763	.636	.907	.600	1.630	2.500	.240
1967	.912	.763	.912	.631	1.660	2.517	.169
1968	.736	.660	.636	.631	1.670	2.500	.213
1969	.752	.646	.602	.630	1.670	2.259	.225
1970	.781	.689	.813	.630	1.480	2.253	.238
1971	1.086	.983	.893	.545	1.660	2.340	.225
1972	.907	.868	.777	.543	1.590	2.396	.248
1973	1.055	.939	1.133	.563	1.465	3.099	.243
1974	1.882	1.565	1.509	.789	3.070	4.128	.401
1975	2.308	2.060	2.089	1.091	3.207	5.034	.395
1976	1.935	1.791	1.764	1.045	2.799	3.560	.471
1977	2.011	2.220	2.065	1.205	2.770	5.273	.586
1978	2.000	1.900	1.641	1.033	2.350	4.906	.483

Appendix table 3--Expected yields

Year	Corn	Sorghum	Barley	Oats	Wheat	Soybeans	Cotton
	<u>Bushels</u>						<u>Bales</u>
1954	32.973	10.212	22.593	28.800	16.351	19.229	364.580
1955	36.038	13.683	23.847	29.746	17.312	19.762	376.806
1956	39.006	16.966	25.063	30.639	18.230	20.338	388.158
1957	41.877	20.061	26.241	31.479	19.105	20.865	398.637
1958	44.651	22.967	27.379	32.267	19.936	21.374	408.243
1959	47.328	25.686	28.479	33.001	20.725	21.864	416.975
1960	49.908	28.215	29.541	33.682	21.470	22.336	424.834
1961	52.390	30.557	30.564	34.311	22.171	22.790	431.820
1962	54.776	32.710	31.548	34.886	22.830	23.225	437.932
1963	57.065	34.674	32.493	35.409	23.445	23.642	443.170
1964	59.256	36.451	33.400	35.879	24.018	24.040	447.536
1965	61.351	38.039	34.268	36.296	24.547	24.421	451.027
1966	63.348	39.439	35.098	36.659	25.032	24.782	453.646
1967	65.248	40.650	35.888	36.970	25.475	25.126	455.391
1968	67.052	41.673	36.641	37.228	25.874	25.451	456.263
1969	68.758	42.508	37.354	37.433	26.230	25.758	456.261
1970	70.367	43.154	38.029	37.585	26.543	26.046	455.386
1971	71.879	43.612	38.666	37.684	26.813	26.316	453.637
1972	73.294	43.882	39.263	37.731	27.040	26.568	451.015
1973	74.612	43.963	39.822	37.724	27.223	26.801	447.520
1974	75.833	43.856	40.343	37.664	27.363	27.016	443.151
1975	76.956	43.561	40.824	37.552	27.460	27.212	437.909
1976	77.983	43.077	41.267	37.386	27.513	27.391	431.794
1977	78.913	42.405	41.672	37.167	27.524	27.550	424.805
1978	79.745	41.545	42.038	36.896	27.491	27.692	416.943

Appendix table 4--Per acre variable costs

Year	Corn	Sorghum	Barley	Oats	Wheat	Soybeans	Cotton
<u>Dollars</u>							
1954	37.706	23.595	18.368	11.598	16.783	17.782	78.201
1955	36.931	23.012	18.752	11.311	16.368	17.100	74.867
1956	35.324	22.375	17.604	10.998	15.915	16.323	70.876
1957	32.268	21.366	18.114	10.502	15.197	16.175	64.275
1958	34.545	21.578	17.828	10.606	15.348	15.993	59.184
1959	36.506	20.966	17.601	10.306	14.913	15.829	65.174
1960	35.553	20.892	17.246	10.269	14.860	15.619	64.129
1961	34.238	20.859	17.322	10.254	14.837	16.740	66.438
1962	34.825	20.855	17.353	10.251	14.834	16.197	65.737
1963	37.191	21.135	17.070	10.389	15.033	17.026	68.637
1964	38.741	20.739	16.062	10.194	14.751	17.990	69.525
1965	39.944	20.656	15.481	10.153	14.692	18.905	66.460
1966	44.514	22.347	17.461	10.984	15.895	20.253	63.944
1967	48.714	24.806	18.267	12.193	17.644	21.973	68.919
1968	48.405	25.067	19.091	12.322	17.830	22.052	71.596
1969	46.078	23.320	18.177	11.463	16.587	22.209	72.165
1970	47.479	23.494	18.743	11.548	16.711	22.319	72.053
1971	54.510	25.609	20.290	12.588	18.215	25.260	81.472
1972	56.428	26.860	21.122	13.203	19.105	26.635	92.629
1973	59.800	35.321	27.699	17.362	25.123	35.851	104.963
1974	88.430	53.790	32.180	21.901	38.260	46.340	165.520
1975	91.210	53.250	39.150	26.440	39.500	47.540	143.990
1976	93.490	54.480	42.690	25.700	39.590	46.900	156.140
1977	96.410	54.180	41.440	26.290	37.240	52.820	168.210
1978	98.270	57.860	44.110	27.780	37.640	54.170	162.540



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